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Sky at Night MAGAZINE REVIEWED IN ISSUE 112 SEPTEMBER 2014 ★★★★★

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Welcome

There's nothing quite like The Northern Lights...

It's hard not to get excited at the prospect of catching a glimpse of the aurora borealis – especially now, as the spring equinox approaches, one of the two points in the year when the chance of seeing the glow reaches its peak. We've got plenty of inspiration and tips about the Northern Lights this month. In the Sky Guide, Pete Lawrence has advice on how to maximise your chances of spotting the display from the UK, while Jamie Carter introduces ways to take great photos of the aurora on page 60. Then on page 36, you can read about my recent trip to Swedish Lapland, a magical setting to see the aurora.

My smartphone's camera was invaluable on that journey, helping me capture the evening skies with the help of photo apps. Will Gater looks at using your smartphone for astrophotography in more detail this month, covering suitable night-sky targets and the imaging techniques that will deliver the best results. You can read his feature on page 30. We stay with smartphones on page 68, where Mark Parrish shows you how to craft your own adjustable smartphone holder that will fix your phone to the eyepiece of a telescope or pair of binoculars.

The best targets for afocal imaging and visual observing are all in The Sky Guide on page 43. Here you'll find details of a fantastic planetary line-up early in the month, how to maximise your chances of observing the delicate zodiacal light, and enthralling tours of the night sky to take with telescope or binoculars. Bring your Sky Guide along with you – as it's now a pull-out!

Enjoy the issue,

Chris Bramley, Editor

PS Our next issue goes on sale 21 March.

Sky at Night – lots of ways to enjoy the night sky...

Television
There's no episode of *The Sky at Night* in March, but you can catch up with old episodes online

Online
Visit our website for reviews, competitions, astrophotos, observing guides and our forum

Facebook
All the details of our latest issue, plus news from the magazine and updates to our website

Podcast
The *BBC Sky at Night Magazine* team and guests discuss the latest astro news

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eNewsletter
The best targets to observe each week, delivered direct to your inbox: **bit.ly/sky-enews**

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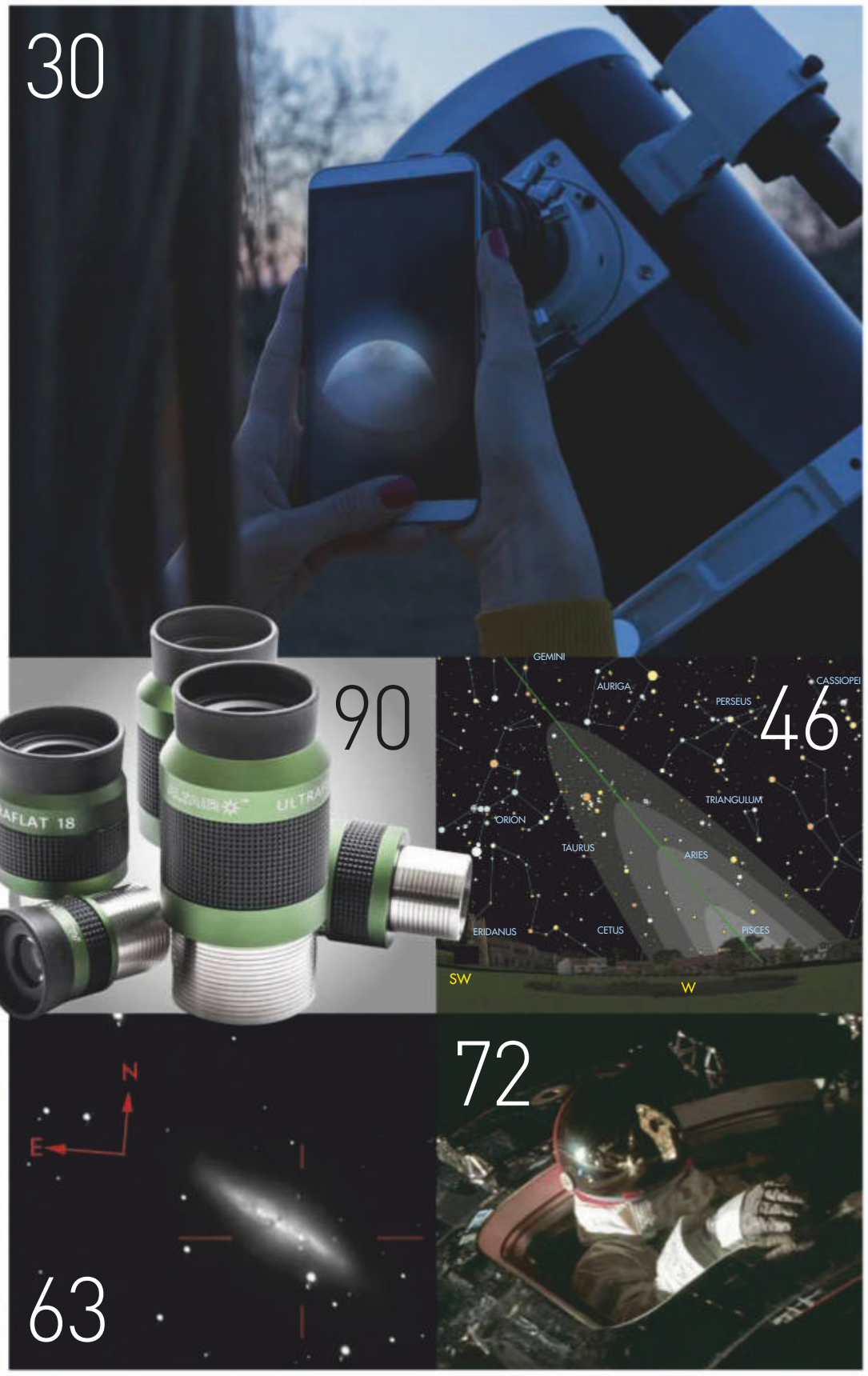
To get started, check out our guides and glossary at
www.skyatnightmagazine.com/astronomy-for-beginners



This month's contributors

Shaoni Bhattacharya

Science writer

Cosmic dust – it's everywhere! But what does it tell us about the Universe? See page 98

Amber Hornsby

Astro research student

Amber reviews Alan Boss's new book, *Universal Life*, on page 95 – and it's a real page-turner

Chris Lintott

***Sky at Night* presenter**

What does it mean when researchers find salt swirling around a protostar? Chris tells us on page 15

Andrew Pontzen

Cosmologist

There's a debate raging about the expansion of the Universe. Andrew talks us through it on page 18

Extra content ONLINE

Visit **www.skyatnightmagazine.com/bonuscontent**, select March's Bonus Content from the list and enter the authorisation code **KWP9NTR** when prompted

March highlights

Watch *The Sky at Night*

Catch the special episode when the team visited NASA to witness the moment the New Horizons spacecraft flew by Ultima Thule on the edge of the Solar System. Pete Lawrence reveals how to observe another Kuiper Belt object: the dwarf planet Eris.

Interview: completing the dark energy survey

Telescope scientist Tim Abbott gives us the latest from a mission to find out what's accelerating the expansion of the Universe.

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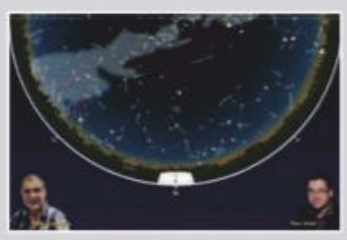


The virtual planetarium

March's night-sky highlights with Paul Abel and Pete Lawrence

ESA/HUBBLE & NASA/CRAMER ET AL.

EYE ON THE SKY

Space can be such a drag

It's not easy being a galaxy in a cluster, hauled into the centre to die by the gravitational tug from larger objects

HUBBLE SPACE TELESCOPE, SUBARU TELESCOPE, 28 JANUARY 2019

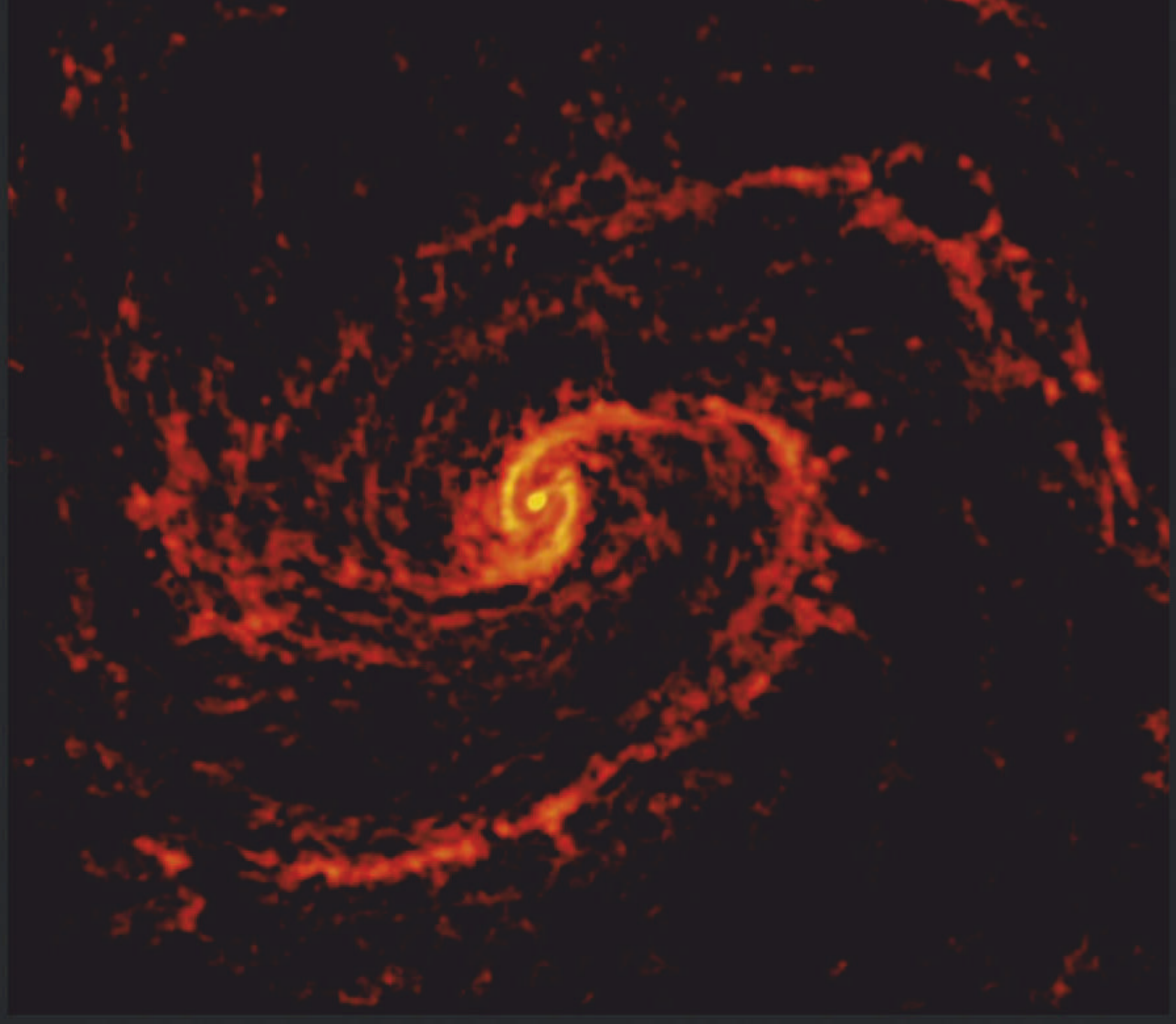
The inky blackness between galaxies and stars in astrophotos might seem like empty space, but this is not always the case. The huge red beam stretching across this image of the Coma Cluster is generated by a process known as 'ram-pressure stripping'. As galaxies move within a cluster, they are actually pushing through hot gas and dense plasma, which drags on the galaxies like the drag on a boat pushing through water. Galaxy D100, on the far right of the image, is being pulled towards the centre of the cluster by the gravitational tug of other galaxies there. As this happens, the drag causes enormous amounts of gas to be stripped from D100, creating a huge tail in its wake. Once the galaxy loses all of its gas, unable to create new stars, it will fade and die.

ESO, NASA/ESA A. FIELD (STSCI), M. DURBIN, J. DALCANTON, AND B. F. WILLIAMS (UNIVERSITY OF WASHINGTON), ALMA (ESO/NAOJ/NRAO) NRAO/AUI/NSF/B. SAXTON, X-RAY: NASA/CXC/COLUMBIA UNIV./A. JOHNSON ET AL/OPTICAL: NASA/STSCI

◁ The beauty of a dying star

VERY LARGE TELESCOPE, 22 JANUARY 2019

Astronomers estimate that our Sun will end its life billions of years from now as a hot dwarf star, shedding layers out into space and forming a glowing planetary nebula. It may look something like this object, ESO 577-24. The hot stellar core is emitting intense ultraviolet radiation, enough to ionise the drifting outer layers and create a glowing cosmic cloud.



◁ Seeing in CO

ATACAMA LARGE MILLIMETER/ SUBMILLIMETER ARRAY, 9 JANUARY 2019

Looking like the sketches of deep-sky objects made by 19th-century astronomers, this image shows the carbon monoxide in Messier 100, a spiral galaxy 55 million lightyears away. The image is part of ALMA's PHANGS survey to study the effect of star formation on a galaxy's shape.

More **ONLINE**

A gallery of these and more stunning space images

◁ Triangulum mosaic

HUBBLE SPACE TELESCOPE, 7 JANUARY 2019

It took 54 images to create this mosaic of the Triangulum Galaxy, M33, 33 million lightyears away. Some 40 billion stars reside within the galaxy and this Hubble image is the most detailed capture of it to date.

△ Punching out from a black hole

CHANDRA X-RAY OBSERVATORY, 9 JANUARY 2019

Spinning black holes, like the one seen as a white blob at the centre of this X-ray image, can fire out powerful jets of material as they devour cosmic matter. Here, something remarkable is happening: one such jet has bounced off a wall of gas, punching a hole in a cloud of energetic particles before slamming into the gas once more. The impact appears as a prominent white spot on the left.

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Panorama II eyepieces are available as 5mm (1.25"), 10mm (1.25"), 15mm (2") and 21mm (2").

BBC Sky at Night Magazine ★★★★★ REVIEWED IN Issue 156 May 2018

Sky at Night says:

"We really enjoyed using these eyepieces and heartily recommend them to intermediate and more experienced observers."

	Article No.	Price in £
1,25" Panorama II eyepiece 5mm		
H in mm 112, ø in mm 49, weight 320g	53649	**179.00**
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H in mm 101, ø in mm 56, weight 375g	53650	**179.00**
2" Panorama II eyepiece 15mm		
H in mm 118, ø in mm 66, weight 600g	53684	**206.00**
2" Panorama II eyepiece 21mm		
H in mm 118, ø in mm 71, weight 705g	53561	**206.00**

BULLETIN

Research suggests the building blocks of life arrived after Earth had cooled

ISTOCK

The Moon brought elements of LIFE TO EARTH

Carbon and nitrogen probably arrived on the back of another planet

The elements necessary for life probably arrived on Earth during the explosion which created the Moon, a novel set of experiments has revealed.

According to current theory, Earth was extremely hot just after it first formed. However, many of the elements in our planet's crust – including those, like carbon and nitrogen, essential to living organisms – are volatile, meaning they would have boiled away. One theory to explain how they are present suggests that another object crashed into Earth after the planet cooled down, delivering the elements to the crust.

"But the timing and mechanism of volatile delivery has been hotly debated," says Rajdeep Dasgupta from Rice University, who took part in the study. The main issue is that the raw material the planets formed from has the wrong ratio of carbon and nitrogen. This means that whatever object brought these elements to Earth had already undergone some kind of geological changes, like the early phases of planet formation.

Dasgupta's team considered whether the material may have already begun to form into an infant planet. We know one of these, Theia, collided with Earth 4.4 billion years ago in an impact which resulted in the Moon. The group ran experiments simulating the high temperatures and pressures found in planetary cores and found that when the sulphur content increases, the ratio of carbon and nitrogen changes to similar levels found on Earth. "This suggests that a rocky, Earth-like planet gets more chances to acquire life-essential elements if it forms and grows from giant impacts with planets that have...building blocks...from different parts of a protoplanetary disc," says Dasgupta.

www.rice.edu

Comment

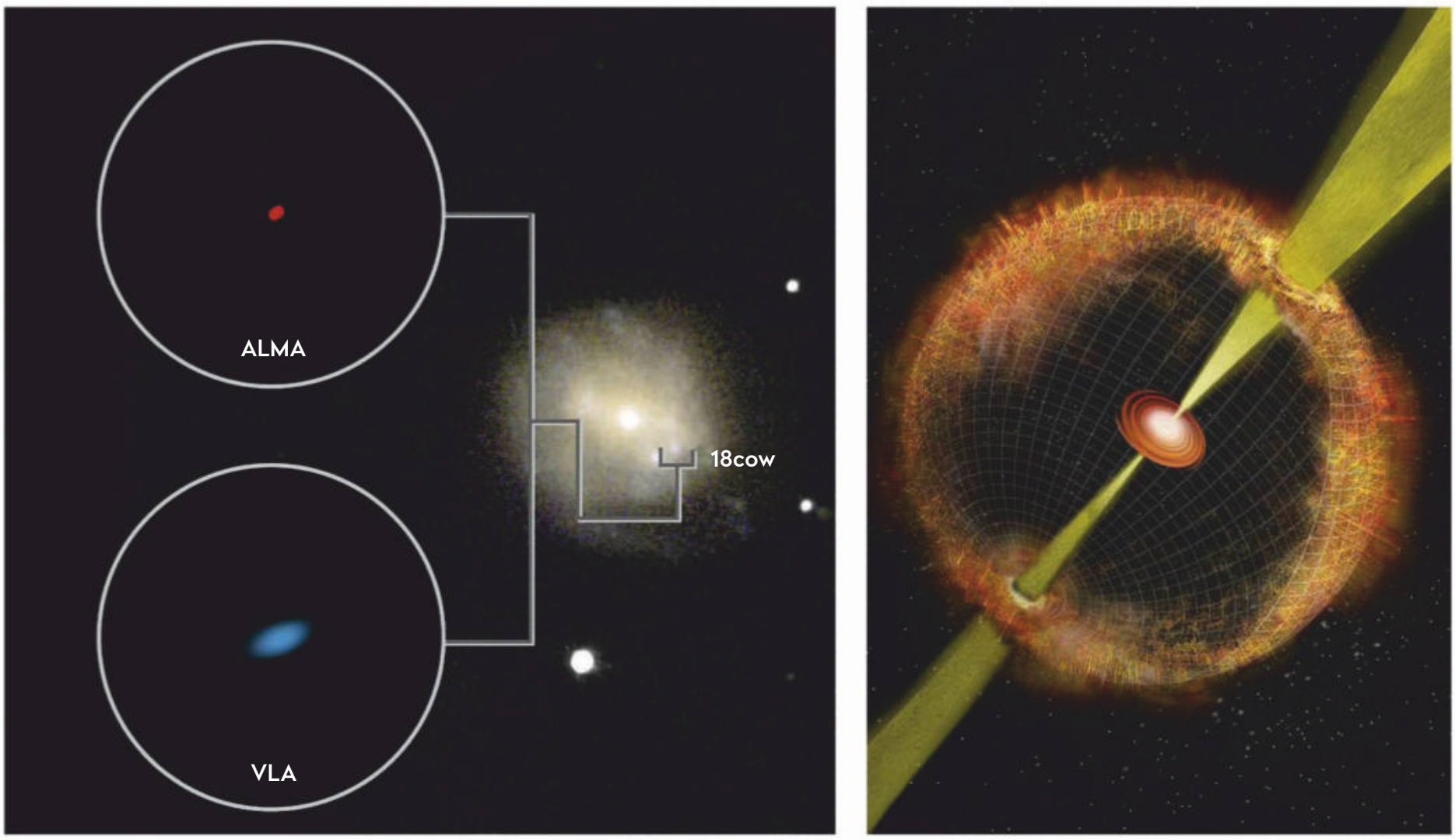
by Chris Lintott

The modern picture of planet formation is one of change and chaos. There may have been as many as 30 large bodies pinging around the inner Solar System early on, with collisions between them responsible for such phenomena as the Moon's formation, Venus's slow rotation and Mercury's strangely high density. All can be explained if the first stage of planet formation delivers a plethora of small worlds, many of which are destroyed or, more likely, expelled from the system. If such collisions are common and bring volatiles to newly forming planets, then we should expect rocky planets everywhere to come loaded with the ingredients of life. Earth and its Moon may not be as unique as they seem.

Chris Lintott co-presents *The Sky at Night*

The latest astronomy and space news, written by Elizabeth Pearson

BULLETIN



▲ ALMA and VLA images of AT2018cow (left); artist's conception of the cosmic blast, with a central black hole pulling in material (right)

SOPHIA DAGNELLO/NRAO/AUI/NSF/R. MARGUTTI/W.M. KECK OBSERVATORY/HO ET AL, BILL SAXTON/NRAO/AUI/NSF, UNIVERSITY OF WARWICK/MARK GARLICK X 2, CALTECH/R. HURT (IPAC)

New stellar explosion lights up sky

The detonation was many times brighter than a supernova

Astronomers have discovered a new type of stellar explosion being driven by an unknown energy source. The flash was up to 100 times brighter than the average supernova and lasted just 16 days.

The outburst, called AT2018cow or 'The Cow', was first spotted by the ATLAS All-Sky Survey on 16 June 2018, but was only recently announced after months of detailed follow-up observations by telescopes around the world, including the Very Large Array (VLA).

"This was an incredibly luminous event, brighter than almost any supernova we've ever seen before," says Daniel Perley from Liverpool John Moores University, who took part in the study. "The Cow appeared and faded away very quickly: so quickly that existing supernova models can't properly explain it," says Perley. "It must be a new type of extremely energetic, explosive event."

Astronomers are currently debating exactly what The Cow is, and what mechanism might be driving it. Initially, the explosion was thought to be a supernova, but its brightening pattern and spectra do not resemble the typical death throes of a star.

Unlike supernovae which dim smoothly over time, this explosion faded unevenly, suggesting it was being 'driven' from within by some unknown, long-lasting power source that kept pumping energy into the material of the explosion as it expanded.

"If it is a supernova, then it is unlike any supernova we have ever seen," says Anna Ho, from the California Institute of Technology, who led some of the follow-up studies of the event.

Another theory being considered is that it's a large star being shredded by a supermassive black hole. However, the region in which The Cow detonated is not one in which astronomers would expect to find black holes of that size.

A third alternative is that the explosion is part of the birth of either a black hole or a rapidly rotating neutron star, called a magnetar.

"We know that black holes and neutron stars form when a star dies, but we've never seen them right after they are born," says Raffaella Margutti, of Northwestern University, who has also studied The Cow.

Astronomers will continue to take new observations, and monitor the skies for signs of another example of this surprising new phenomenon.

www.fallingstar.com

▲ An artist's impression of the double star system with the surrounding dust ring 'flipped' on its side

Double stars have a flipped disc

The ring of gas circles the poles not the equator

New observations by the Atacama Large Millimetre/ Submillimetre Array (ALMA) have found a double star system surrounded by a ring of dust that's been knocked over on its side.

The dusty ring is a protoplanetary disc, which could one day form planets. Though planetary systems have been found around binary stars before, this is the first time they have been found at right angles to the stars' orbit.

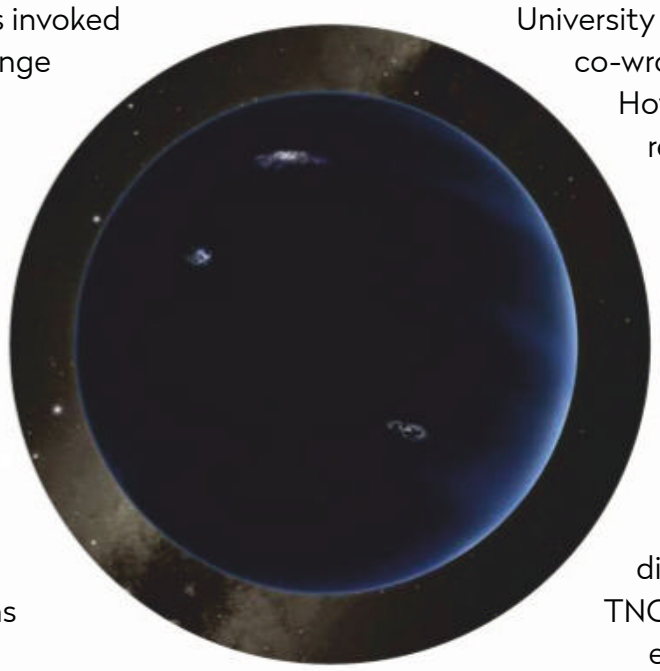
"Some of these planets end up being misaligned with the spin of the star, so we've been wondering whether a similar thing might be possible for circumbinary planets," says Grant M Kennedy from the University of Warwick. Kennedy and his fellow researchers used ALMA to measure the ring's orientation. If planets did form, they would have two suns that moved from side to side across the sky and some extremely unusual seasonal variations.

www.almaobservatory.org

Calling time on Planet Nine

Planet Nine may not exist after all. The idea of a ninth planet was invoked in 2016 to explain the strange behaviour of around 30 Trans-Neptunian Objects (TNOs). But a new study investigated whether their own cumulative gravity could instead be the culprit.

"If you remove Planet Nine from the model and instead allow for lots of small objects scattered across a wide area, collective attractions between those objects could just as easily account for the eccentric orbits we see in some TNOs," says Antranik Sefilian from the University of Cambridge, who co-wrote the study.



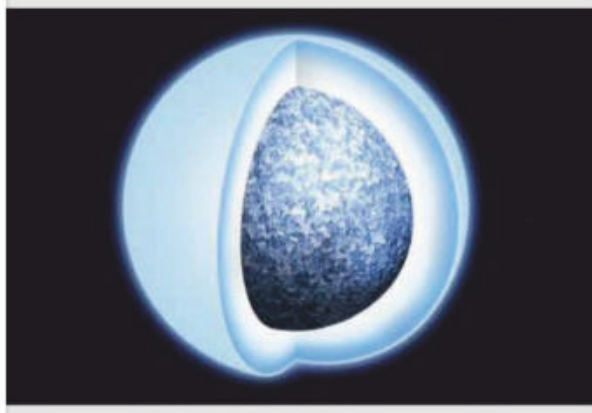
▲ Gravity rather than a ninth planet may be behind the mysterious orbits of the objects beyond Neptune

However, this new theory requires there to be as much as 100 times more mass in the disc than has currently been accounted for.

"It's also possible that both things could be true – there could be a massive disc and a ninth planet. With the discovery of each new TNO, we gather more evidence that might help explain their behaviour," says Sefilian.

www.cam.ac.uk

NEWS IN BRIEF



The Sun's diamond future

A recent survey has revealed that when Sun-like stars reach the end of their lives, the carbon and oxygen in their cores crystallises. The process, which our own star will undergo in 10 billion years, slows down the rate of aging. This keeps stars within a certain colour and luminosity range, creating an excess that the survey detected.

What time is it on Saturn?

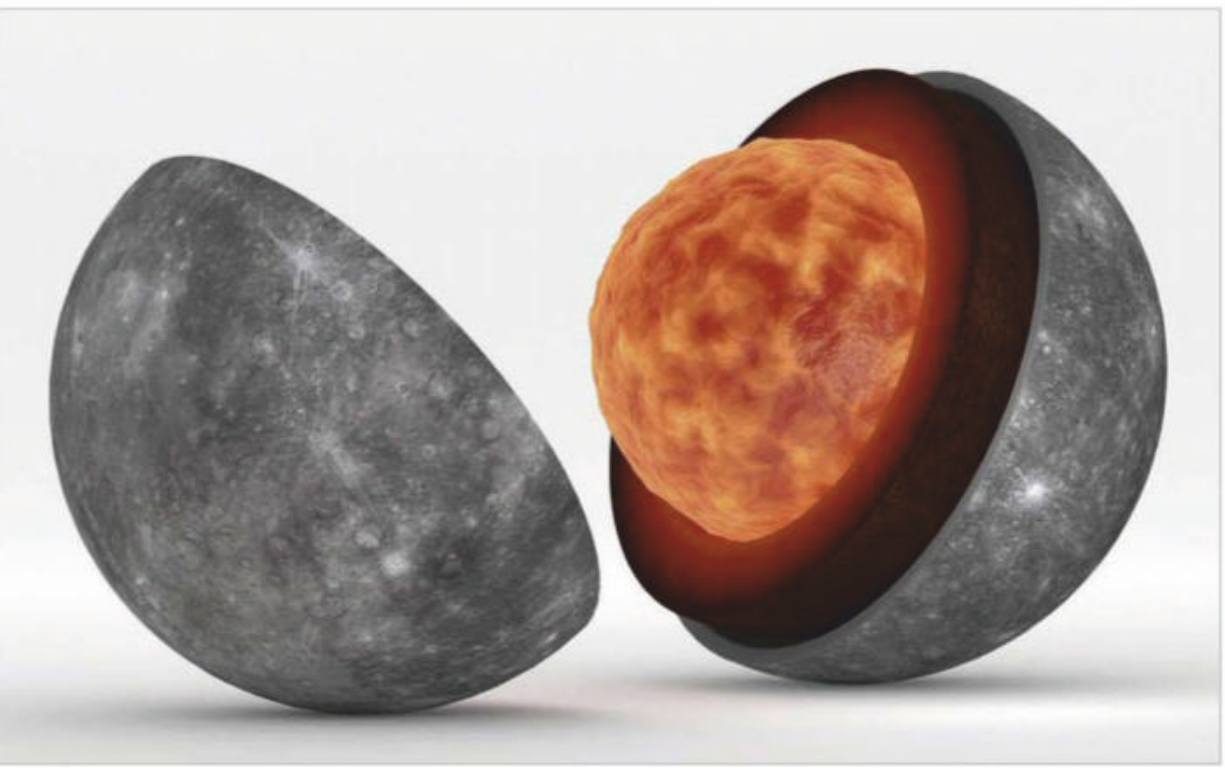
Astronomers at NASA have measured the length of a day on Saturn for the first time. The team took a new look at images of the planet's rings taken by spacecraft Cassini, hunting for patterns created by the movement of the planet's solid core. They found it takes Saturn's core 10 hours, 33 minutes and 38 seconds to completely rotate.

TESS finds first planets

The exoplanet-hunting satellite TESS has found three confirmed – and 280 candidate – planets within its first three months of observing. The NASA mission will spend at least two years searching for planets around bright stars, hopefully discovering as many as 10,000, as well as supernovae and transient events.

Our experts examine the hottest new research

CUTTING EDGE



DIEGO BARUCCO/ALAMY STOCK PHOTO, STOCKTREK IMAGES INC./ALAMY STOCK PHOTO

◄ Mercury's large, dense core has always been a puzzle, but researchers may now have unlocked how iron-rich planets like this are built

Did magnetism make Mercury?

The Sun's magnetic field may be behind Mercury's mysterious core

Mercury is the smallest planet in our Solar System, as well as being the closest to the Sun and the one with the most elliptical orbit. In some respects it is also the most mysterious. For such a small planet, it's fabulously dense, so much so that its heavy iron core is estimated to make up around two-thirds of its mass. Proportionally it's over twice as big as the cores of the other rocky, terrestrial planets, Earth, Venus and Mars.

All terrestrial planets are made up of an iron-rich core with an overlying silicate-rich mantle and crust. But what gave Mercury such a giant heart? Computer simulations of the early Solar System, modelling how small planetesimals collide and aggregate to grow into planets, fail to show how an inner world like Mercury could ever form with such a large iron core.

Several explanations have been put forward. Perhaps Mercury didn't in fact form with such a swollen centre, but suffered the loss of most of its original silicate-rich mantle early in its history, leaving behind a planet with a disproportionately large core. Maybe this outer mantle was blasted away by a huge impact, or a hot proto-sun boiled away its top layer.

Now, Maximilian Kruss and Gerhard Wurm, both at the University of Duisburg-Essen in Germany, have come up with a new hypothesis to account for mysterious Mercury. They note that several exoplanets have also been found to be very dense, and that even within our own Solar System there is a general pattern of decreasing iron content from the innermost to the outermost planets. Perhaps, they say, Mercury's large iron core was produced not by a freak occurrence, but as the result of a common process in planet-building.

Kruss and Wurm think that the interplay between magnetism and iron-rich particles may be the key. The inner part of protoplanetary discs can be threaded with strong magnetic fields from the forming star. In the first stage of planet-building, dust particles need to collide and combine together into bigger and bigger aggregates. But once aggregates get to a certain size they tend to bounce off each other, which hampers the growth process. What the researchers suggest is that a surrounding magnetic field would help iron-containing particles to stick together, and so planetesimals forming in the innermost region of protoplanetary discs would tend to become more iron-rich and build Mercury-like planets.

"The clusters grew much larger with a stronger magnetic field or higher ratio between iron and silicate in the particles"

They have tested their idea with experiments: floating dust grains of different iron-silicate compositions to watch them collide and aggregate with each other, all while surrounded by a magnetic field. And indeed they found that the clusters grew much larger with a stronger magnetic field or higher ratio between iron and silicate in the particles.

If they're right, this could go a long way to neatly explaining why Mercury is so dense with a large core.

Prof Lewis Dartnell is an astrobiologist at the University of Westminster and author of *Origins: How the Earth Made Us* (geni.us/origins)

Lewis Dartnell was reading... *Seeding the formation of Mercurys: An iron-sensitive bouncing barrier in disk magnetic fields* by Maximilian Kruss and Gerhard Wurm. **Read it online at arxiv.org/abs/1812.05338**

Orion's salty star

A sprinkling of salt could allow astronomers to watch stars grow

Wherever stars are forming, astronomers have come to expect a disc of material to form too. Such discs eventually provide the site and the raw material for planets to grow, but they have another important role that starts long before that.

A protostar grows through accreting material from the disc. But there are powerful winds that sweep up material from the disc, taking it away from the growing star. Eventually this removal of material brings a halt to the accretion process.

Or at least, that's what we assume. It's hard to actually observe discs while stars are forming, especially for the most massive specimens where such a disc might exist only while the protostar is very young. To peer into the mysteries of star formation, astronomers normally turn to what's known as the sub-millimetre region of the electromagnetic spectrum, where the molecules that form in the environment around young stars reveal themselves. (The sub-millimetre sits between radio and the infrared, in the same wavelength range a microwave uses.) The trouble is that most molecules you might think of observing also occur in the material around the star itself or – worse – throughout the interstellar medium, making it hard to pick out the subtle signature coming from the disc.

Researchers have now found a way to crack this problem using, of all things, salt. They employed the Atacama Large Millimeter/Submillimeter Array (ALMA) – sensitive, as the name suggests, in the sub-millimetre – to stare at the nearest massive protostar believed to have a disc, Orion Source I. Mysterious lines had previously been spotted in the spectrum of the growing star, but the ALMA observations managed to identify these as sodium chloride and potassium chloride – exactly the same chemicals that live in your tabletop salt shaker.

The attraction of salts in space is that they're rare. They're only seen in and around the disc itself, meaning that for the first time we can access information about the disc. But they bring a mystery with them – how did salts come to be there in the first place?

▼ **Salt found swirling in the disc of Orion Source I gives a tantalising hint at how stars are formed**

"They identified sodium chloride and potassium chloride – exactly the same chemicals that live in your tabletop salt shaker"

The team aren't sure. It seems likely that the salts form because of the effect of the harsh protostellar environment, filled with high-energy particles thrown off in the star's unstable stellar wind. Such particles could slam into dust particles in the disc and in the outflowing material that rushes away from it, liberating molecules from the dust grains and creating a gas where they can react – but at this point we can't be sure.

Nor do we know how the salt molecules became excited enough to emit strongly enough to be detected by ALMA. And, most importantly, because this is only one star we don't know whether the salty story of Orion Source I tells us a general lesson about how such stars form, or whether this is just a one-off. There's a lot more staring at salt to be done if we're to really get to the bottom of how massive stars like this one form.

Prof Chris Lintott is an astrophysicist and co-presenter of *The Sky at Night* on BBC TV. He is also director of the Zooniverse project

Chris Lintott was reading... *Orion Source I's disk is salty* by Adam Ginsburg et al. **Read it online at arxiv.org/abs/1901.04489**

NEWS IN BRIEF

Exoplanet plugs the gap

A rare exoplanet has recently been discovered by a group of citizen scientists. At around twice the radius of Earth, K2-288Bb lies within a size 'gap' of planets between 1.5 and 2 Earth radii, where there is a curious lack of worlds. It was found by users of the Exoplanet Explorers website, using data from the Kepler Space Telescope.

Repeat performance for fast radio bursts

A second repeating fast radio burst (FRB) has been discovered, it was announced in January. FRBs are intense pulses of energy, though no one currently knows what generates them. Over 60 have been discovered, but while most of them flash only once, this FRB flashed several times over three weeks.

Earth's oldest rock found on the Moon

The Earth's oldest rock has been found not on our planet, but on the Moon. Recent analysis of lunar rocks brought back by Apollo 14 found a small sample of material which originated on Earth. It's thought the rock was launched into space by a meteor impact four billion years ago, before coming to rest on the Moon.

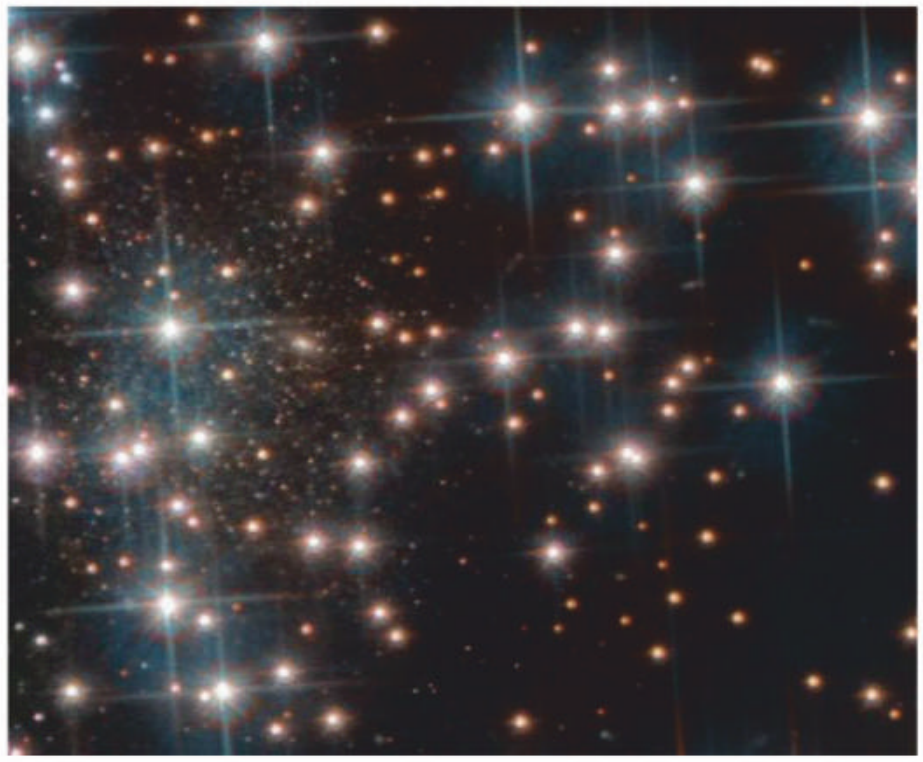
NASA'S GODDARD SPACE FLIGHT CENTER/FRANCIS REDDY, ESA/HUBBLE/NASA/BEDIN ET AL., JOSE M MADIEDO

The latest astronomy and space news, written by Elizabeth Pearson

BULLETIN

Milky Way gets a new neighbour

The galaxy appears to be 13 billion years old



▲ New galaxy Bedin 1 was discovered by chance behind NGC 6752

Astronomers have recently discovered a new nearby galaxy in the Milky Way's galactic neighbourhood, the Local Group.

They found the galaxy, Bedin 1, by chance while studying white dwarf stars in the globular cluster NGC 6752 with the Hubble Space Telescope, and noticed a compact collection of stars on the edge of the image. Closer inspection revealed the collection was much further away than the cluster – around 30 million lightyears from the Milky Way.

The galaxy is elongated in shape, and only 3,000 lightyears long (the Milky Way is roughly 200,000) making it a dwarf galaxy. There are 36 galaxies of this type known in the Local Group, but most are satellites of larger galaxies.

Bedin 1 is also extremely isolated. Its solitary position means the dwarf has had little interaction with other galaxies, giving astronomers the opportunity to study a galaxy that has grown up alone.

www.spacetelescope.org

Meteor hits the red side of the Moon

On 21 January, astronomers were given an unexpected treat while watching the lunar eclipse. At 04:41 GMT a meteor thudded into the Moon's surface, creating a bright flash.

Light is created by the energy of the impact and the bigger the meteor, the brighter the flash. Though several small meteors hit the surface every day, an impact this bright only happens once every two to three months.

"The flash reveals that a rock hit the Moon at a large speed – about 61,000km/h. When these hypervelocity impacts occur, the impactor is destroyed and a brief flash of light is emitted," says José M Madiedo of the Universidad de Huelva, who runs the Moon Impact Detection and Analysis System (MIDAS) which monitors asteroids hitting the Moon.

▲ The meteor impact occurred just a few minutes before the Moon was fully eclipsed

Usually, MIDAS can only look out for impacts on the night side of the Moon, as the flashes contrast against the dark background. "Monitoring during eclipses opens a new observation window," says Madiedo.

www.uhu.es

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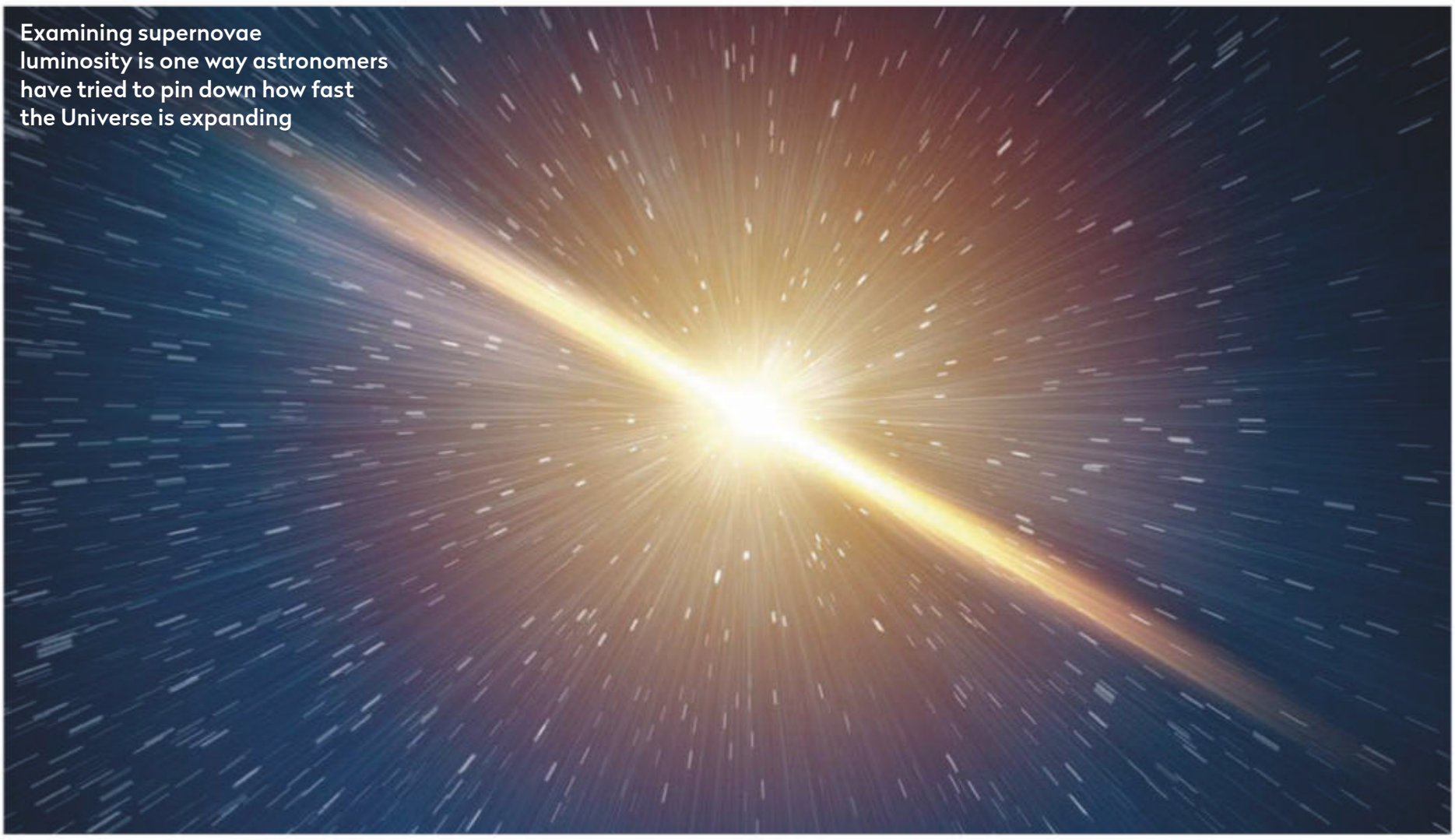
The Sky at Night TV show, past, present and future

INSIDE THE SKY AT NIGHT



Examining supernovae luminosity is one way astronomers have tried to pin down how fast the Universe is expanding

February's *Sky at Night* programme explored the arguments around the expansion of the Universe. Cosmologist **Andrew Pontzen** tells us more

The Universe itself is expanding. It's approaching a century since astronomers reached this startling conclusion. But over the last three years, controversy has erupted over the precise stretching rate. Depending on which measurements you believe, galaxies a billion lightyears from us race away at either 74 or 80 million km/h. That's a modest discrepancy — but it might signal the start of a revolution.

Controversy over expansion measurements is nothing new. Right up to the 1990s, warring factions of astronomers obtained numbers which differed by factors of two or more. To understand how it's possible to get such wildly different estimates, we have to take a look at the challenging observations involved.

Pinpointing objects in 3D space requires the construction of an elaborate system of interlocking measurements known as a distance ladder. Technologies like radar form the rock-solid base of the ladder: they reveal distances in our Solar System in much the same way as an airport tracks planes. But, on its own, this approach can't reach deeper space, since the radar signal becomes too faint.

To find the distance to more remote objects we need further rungs on the ladder: parallax, Cepheid variable stars, and finally supernovae. The physics becomes increasingly intricate, so that each step must be verified and calibrated by comparison with its predecessor.

Up on the top rung, supernovae enable measurements of the vast distances required to probe cosmic expansion. Launched in 1990, the Hubble Space Telescope enabled a precise ladder to be constructed, heralding a golden era of agreement. Repeated studies confirmed (within the known margin of error) the same value: 80 million km/h for a galaxy at one billion lightyears.

Cosmologists wade in

But at the same time as astronomers consolidated the bottom of the ladder, cosmologists were inching down from the top using measurements of the cosmic microwave background – remnant radiation from the Big Bang. Ripples in that radiation represent

ISTOCK, NASA, BBC

Andrew Pontzen is Associate Professor of Cosmology at University College London

sound waves that traversed the early Universe. Since we can calculate the speed of sound throughout cosmic history, observing those waves lets us triangulate the sky. The basic physics resembles how bats echolocate their prey, giving a completely independent way of inferring distances.

At first, cosmologists applying this technique seemed to be honing in on a value that agreed with the astronomers: a spectacular success. But as the accuracy increased, by 2015 the precise values were differing, with cosmologists now preferring 74 million km/h for that galaxy at a billion lightyears.

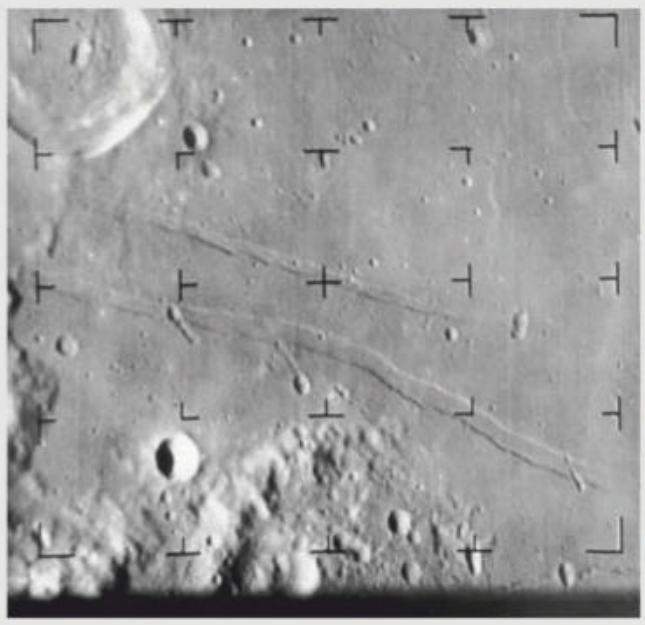
One possible interpretation is that the intricate astronomical ladder has a fracture in it. The slightest mistaken calculation or assumption on any of the rungs could cause the top of the ladder to be shaky. But there is no agreement on exactly where the problem might be: astronomers feel convinced that the margin for error is just not that big.

A more intriguing possibility is that cosmologists' assumptions about the sound waves may be inaccurate. Including unexpected, exotic new particles in the early Universe could shift the calculations, perhaps back into agreement. If this explanation gains traction, we'll be scrambling to rewrite the particle physics textbooks.

Looking back
The Sky at Night
March 1965

On the 13 March 1965 episode of *The Sky at Night*, Patrick Moore discussed the latest images sent back from the Moon by NASA's Ranger 8 spacecraft. The Ranger missions were a series of robotic probes intended to crash into the Moon in the early 1960s. As they made their approach, the spacecraft filmed the lunar surface before impacting at high speed.

Out of seven previous Ranger missions, only one had succeeded, and so NASA breathed a sigh of relief when on 20 February 1965, Ranger 8 successfully hit the surface.



▲ **Ranger 8's image of the Mare Tranquillitatis, taken four minutes before impact**

The main goal of the mission was to scout out the terrain where Apollo 11 would set down just four years later. But when Patrick analysed the images just after the impact, he was trying to answer one of the biggest questions about lunar formation: what role did volcanism have in creating the lunar surface? Within the Ranger 8 images there appeared to be signs of the tubes and cavities usually associated with lava fields here on Earth, suggesting the Moon had been volcanically active at some point in its past.

There will be no episode of *The Sky at Night* this month, but Chris, Maggie and the team will return in April for more space and astronomy adventures. In the meantime, you can watch archive episodes and clips of the show, view astrophotography galleries and access practical astronomy guides, test your space knowledge with astronomy quizzes and find out when the next episode will be broadcast on the official *Sky at Night* website. The programme returns to BBC Four in April.

BBC www.bbc.co.uk/skyatnight

▲ **Chris Lintott and Maggie Aderin-Pocock will return to our screens in April**

Emails – Letters – Tweets – Facebook – Kit questions

INTERACTIVE

Email us at **inbox@skyatnightmagazine.com**

MESSAGE OF THE MONTH

This month's top prize: four Philip's books

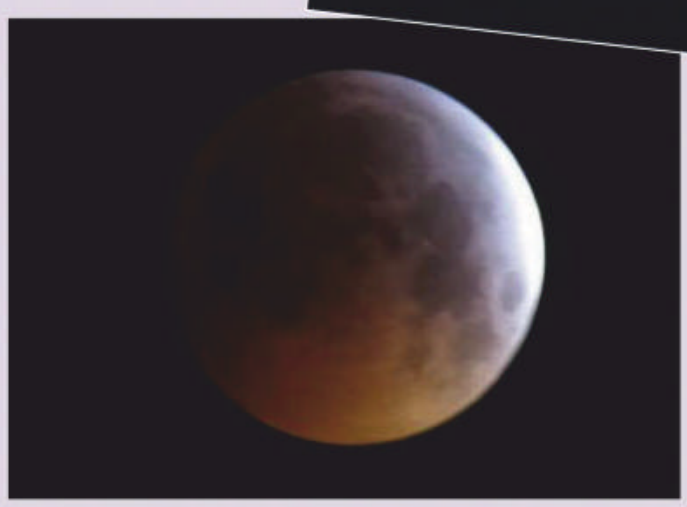
PHILIP'S The 'Message of the Month' writer will receive four top titles courtesy of astronomy publisher Philip's: Robin Scagell's *Complete Guide to Stargazing*, Sir Patrick Moore's *The Night Sky*, Mark Thompson's *Stargazing with Mark Thompson* and Heather Couper and Nigel Henbest's *2019 Stargazing.*

Winner's details will be passed on to Octopus Publishing to fulfil the prize

Reward for the early risers

Inspired by your piece on photographing a lunar eclipse in January's edition, I set my bedside alarm (repeatedly) throughout the night to ensure I was there at the right times to capture the 'highlights' of the event. Fortunately, the astronomy gods were smiling on me as a cloudy forecast held off and I successfully captured shots showing the Moon at several stages of the eclipse.

I lack the software and equipment to add that extra level of polish of the seasoned imagers among your readers. Despite this, the photos have still gone down a treat (much to my surprise) with colleagues and friends alike. It's rewarding to see their interest in the night sky – just like my four-year-old son, who insisted I wake him to see his first total lunar eclipse with Mum and Dad. He couldn't wait to tell his teacher at school about it later!



▼► **Scott and his son were lucky enough to get a clear sky to capture this shot of the lunar eclipse**

I'm delighted to have got the job done and have still had time to just stand there, look up and enjoy the spectacle being laid on for all those willing to brave the cold and lack of sleep. Well done to everyone else who made the effort to see it too.

Scott Cole, Hornchurch

Tweets

Alyn Wallace
@alynwallace • 22 Jan
A 5-hour sequence of the full Moon fading into total eclipse and back again from Belle Tout lighthouse in Sussex (1 shot every 3 mins). The next time this is visible from the UK is not until 2029!

NASA, STEVE RICHARDS

Accidental alien

I have a query regarding your January 2019 issue, and the article by Will Gater: '2019, The Year in Space'. I read it thinking that the Mars InSight lander had already landed on Mars, but when I studied the photo at the top of page 37 I noticed that it included a Martian sitting astride his bicycle! Where was the photo actually taken? Please explain what is going on. A first-class magazine indeed, and I look forward to further space details.

John G Ford, West Sussex

If we squint at the illustration, we can see what you mean! It is in fact the grapple on the end of the deployment arm. ***– Ed***

Fellow fans

It was with pleasure and empathy that I read the message from Adam Delmage (Interactive, February 2019 issue) regarding his son Taylor's excitement at an issue of *Sky at Night Magazine* coming through the letter box. It's the same for me when I visit the newsagent to collect my copy,

and it's disappointing if it hasn't arrived! Taylor is five, and I will be 85 in March, but when we receive our latest issue of the magazine and turn to our favourite sections, the eight decades between us disappear like magic! Congratulations on *Sky at Night Magazine*'s new look, a truly splendid publication has become even better.
Fintan Moran, via email

Dark victory

George Futers's letter about new LED lights blocking out his views of the night sky (February 2019 issue) is something I can relate to. Two years ago my local council replaced the sodium lights which looked over my garden with LEDs. The old lights switched off at 12.30am every night, giving me some observing time, but the new ▸

TALES FROM THE EYEPIECE

There are not many of us who haven't had their patience tested by cloudy skies. How often have we given the sky 'just another half hour' to see if it becomes more favourable? That half an hour may seem like an eternity, but imagine waiting 18 years for the clouds to break. That's what the Chairman of West Didsbury Astronomy Society, Phil Brocklebank, did. Phil's dream was to see a total solar eclipse and, having been beaten by cloudy skies in the UK in August 1999, his determination paid off two decades later with a second crack at seeing an eclipse from the USA in August 2017. The cloud nearly undid Phil again, but his goal was achieved!

Email your tales to Jon at
TalesfromtheEyepiece@themoon.co.uk

Jonathan Powell is the astronomy correspondent for the *South Wales Argus*

ON FACEBOOK

WE ASKED: Which mystery would you most like to see solved?

John Maclean
Dark matter. If we could solve what it is, we could probably define a theory of everything.

Al Higgs
What was before the Big Bang, and will we ever have an event like that again?

Alan Ford
Whether there's life under the ice of Jupiter's moon Europa.

Tim Cowell
Intergalactic travel.

Bettina Bowyer
To know if Betelgeuse will actually go supernova within the next 1,000 years or less, and what to expect!

AR Gavin
The mystery of Fast Radio Bursts.

Jon Sales
Solid proof that we are not alone in this Universe.

Stuart Gasson
The effects on matter and energy beyond the event horizon of black holes. And can they become partially or even universally massive?

Michael Marshall
How many places actually do have water in the Solar System (frozen or otherwise) apart from Earth, and what is the likelihood of life in those places?

SCOPE DOCTOR

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With **Steve Richards**

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scopedoctor@skyatnightmagazine.com

I have a Synscan 127 Maksutov-Cassegrain and want to use an eyepiece for projection. Would the Baader Hyperion zoom be suitable?

ANDRE HUDSON

▲ A Barlow lens like this one from Explore Scientific may be a less fiddly option

Eyepiece projection is a method of capturing images through a telescope's eyepiece using a camera with its lens removed, and is normally used where high magnification is required, for example when imaging planets or features on the Moon.

One of the issues associated with this method of imaging is attaching the camera adequately to the telescope, ensuring that it is accurately aligned with the eyepiece. There are several mounting systems that clamp onto the eyepiece body, but some eyepieces have a suitable thread built into their top to take an adaptor to produce a very solid and perfectly aligned threaded attachment point. The Baader Hyperion zoom lens has such a thread and would be a good choice. However, this method of photography can be quite fiddly. You would probably achieve better results using a high quality 3x Barlow lens like the Explore Scientific 3x Focal Extender, Celestron X-CEL LX 3x Barlow or a Televue 2.5x Powermate.

Steve's top tip

Why do I need to cool my camera?

The sensor in a digital camera warms up during the long exposures required for deep-sky astrophotography. This energy produces what is known as 'thermal noise', as the heat tricks the sensor into believing that it has received some additional photons. These false detections result in fully saturated pixels being peppered across the image.

Modern astro cameras designed for deep-sky imaging are equipped with Peltier cooling systems that are attached to the rear of the sensor to reduce the temperature by between 25° and 50°C below the ambient temperature, thus dramatically reducing the unwanted noise.

Steve Richards is a keen astro imager and an astronomy equipment expert

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▸ LEDs spilt over into my garden so all I could see were the bright stars and constellations. I put up with it for two years and was about to give up the hobby earlier this year. In desperation, I rang the council. The lady I spoke to didn't seem very helpful, but two days before Christmas I noticed a man in a cherrypicker working on the light, who said he was fitting a blanking plate and checking that the light output had been reduced down to 30 per cent after 12.30am. A near-dark garden – what a present! So I say: before selling up, ring your local council – and never give up hoping.
Jim McNeil, Cotswold Astronomy Group

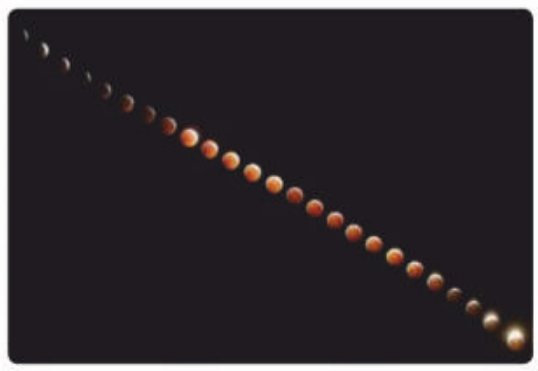
Timing trouble

I took this photo from my garden in Suffolk using a Nikon D5000 and Sigma zoom lens (1' exposure at f/6 with ISO 1600). I'm quite pleased with the result as it's only the second time I've captured such a subject. One thing puzzles me, however. In the January 2019 issue it states that the Moon would be totally eclipsed at 4.41am (The Sky Guide, page 52), but I took this shot at 4.43am and the Moon wasn't yet totally eclipsed. I was unable to get any further shots because very shortly afterwards clouds covered the Moon.
Andy Parrett, via email

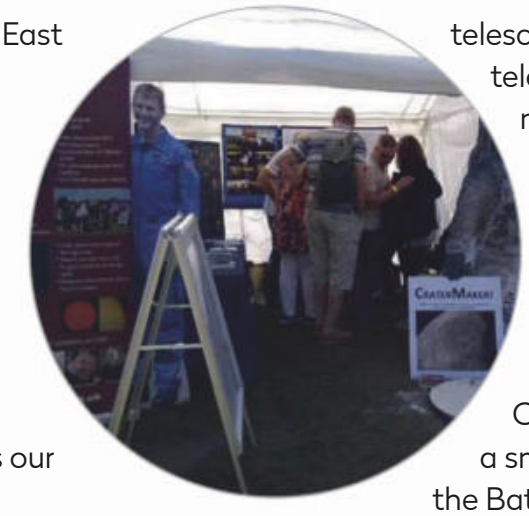
The Moon passed through the very top of the dark umbral shadow this eclipse, hence the lighter shade of the lunar disc's upper limb. ***– Ed***

Tweets

David Forknall
@habrokimaging • 22 Jan
Sequence montage of the super blood wolf lunar eclipse early yesterday morning #SuperBloodWolfMoonEclipse #LunarEclipse #NightPhotography @skyatnightmag



SOCIETY IN FOCUS



Based in Bexhill-on-Sea, East Sussex Astronomical Society was formed in 2000 with Sir Patrick Moore as our Honorary President. We now have over 70 members and, since the sad demise of Sir Patrick, we are honoured to have Professor Chris Lintott as our patron. The society is a registered charity with a simple aim – to help people enjoy astronomy and feel welcome to join our activities.

Our monthly meetings start with a talk from a guest speaker, followed by a coffee break, a raffle and a monthly 'sky diary'. Speakers this year include Bob Mizon, national coordinator for the BAA's Commission for Dark Skies, and astronomer Pete Williamson.

The Society has a dark site on farmland to the north of Bexhill, with its own small observatory housing a 16-inch Meade telescope. We also have several telescopes available to our members on loan.

Some of our members are STEM Ambassadors and attend outreach events such as the annual Astronomy Festival at Herstmonceux Observatory. We also have a small 'satellite' group called the Battle Cosmic Space Explorers. This is a group of about 15 youngsters aged 11–14 who meet once a month to learn about astronomy in an informal, friendly atmosphere. The name of the group was chosen by them.

We're always keen to welcome new members, young, old and in between, expert or beginner. If you'd like to come along to a meeting, please visit our website for details. We would love to see you!
www.eastsussexas.org.uk
Kay Hunting, Secretary, East Sussex Astronomical Society

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British Science Week

Various locations, 8–17 March

The UK celebration of science returns with astronomy evenings, pop-up planetariums, talks and demos around the country.
www.britishscienceweek.org

Public star show

Wynyard Planetarium & Observatory, County Durham, 1, 15 March, 7.30pm

Visit Wynyard Planetarium for a dome show and observing through a 14-inch telescope. Tickets are £6; £3 for children.
www.wynyard-planetarium.net

Practical Astronomy Show

Kettering Conference Centre, Northamptonshire, 9 March, 9.30am

This brand new show brings together astronomers, astrophotographers and telescope makers for a day of talks and exhibitions on practical astronomy. The event is free to attend.
www.practicalastroshow.com

Caithness lunar observing

Castlehill Heritage Centre, 15 March, 7pm

Learn about the tools and techniques needed to observe and photograph the Moon in this free event taking place at a Dark Sky Discovery Site.
www.facebook.com/caithnessastronomygroup

BRITISH SCIENCE WEEK, AMELIE DEBLAUWE X 2, DAN CLARKE, ALICE BOAGEY

PICK OF THE MONTH

▲ A packed fortnight of science and astronomy activities awaits at this year's festival

Cambridge Science Festival 2019

Cambridge, various locations, 11–24 March

This city-wide festival presents talks, demonstrations, performances, guided tours and film screenings over a science-filled fortnight.

Astronomer Royal Martin Rees heads a discussion on the challenges and risks facing humanity over the next century. Other talks include 'The Universe of Black Holes', exploring the science behind the cosmic giants, while 'Lives of Stars' reveals the secrets of stellar evolution. 'Cosmic Quest' looks back over 40,000 years of astronomy and 'The Sound of Space Exploration' is a musical performance created using 40 years of data from the Voyager mission. 'Einstein, General Relativity and Gravitational Waves' will be highlighting the importance of the LIGO experiment.

There will be a practical Moon-watching session, an evening on the history of astronomy and an open night giving the public the chance to meet scientists and learn about the work carried out at this famous institution.

For more info and to see all of this year's events, visit the festival's website:
www.sciencefestival.cam.ac.uk

Edinburgh open evening

Royal Observatory Edinburgh, 6.30pm, 8pm

Every Friday in March the observatory will host two sessions guiding you around the night sky. Included is a tour of the observatory's Victorian telescope dome and stargazing, weather permitting. Tickets are £5; £4 for concessions.
www.roe.ac.uk/vc/public

Cardiff Star Party

CAS Observatory, Dyffryn Gardens, St Nicholas, 8 March, 7.30pm

Join Cardiff Astronomical Society for an evening of stargazing including an astronomy talk, a tour of the night sky and observing through telescopes. Contact
vice.chairman@cardiff-astronomical-society.co.uk

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FIELD OF VIEW

The perils of a perfect picture

From slimy eels to things that go bump in the night, **Stuart McIntyre** braves it all to get his shot

Stuart McIntyre is a professional photographer with a passion for the night sky and landscapes of his native Scotland

Astrophotography can be a bit of an odd hobby. For instance, it was 3.30am when a confused looking policeman joined me on the abandoned pier at Loch Fyne. He asked what I was doing and his puzzled expression didn't disappear when I told him that I was taking photographs (shouldn't the camera have made that obvious?). Since then I have met him a few times, interestingly always the same policeman who seems to be looking for a suspicious person wandering around the west of Scotland at night.

On that night I was heading to Polphail, a village built, fitted and furnished during the oil rush of the 1970s, but never inhabited. Normally at night you can hear the sounds of birds, deer and sheep, but in this derelict village I could hear only silence – except for every couple of seconds a loud metal door slamming. It was a creepy place. I collected my senses and thought to myself that it must be the wind; there'd be nobody who'd make a three-hour journey out here to sit and slam a door all night!

I went on and started to take photographs. That night had the most clear and vibrant Milky Way I have ever seen: it was back in 2014 and I've been very keen to see it that clearly ever since. I was in amongst the buildings and had my camera pointing straight up at the sky overhead; I turned off my head torch and pressed the shutter. While I was enjoying the silence, I had a growing feeling of panic – *the door had stopped slamming*! It is the only time that I've been completely spooked: after that photograph I left quickly.

I always wanted to revisit Polphail and do it justice. Sadly, when I returned in January 2018, all I found was rubble as it had finally been demolished. I have regrets of not staying longer to photograph this amazing place.

On another night I wanted to get a photograph of Kilchrun Castle framed under the Milky Way. There was only one small problem: I had to stand in the middle of Loch Awe to get the particular perspective. However, in an odd way it turned out to be one of the most interesting nights of my photography experience.

Frogs were making lots of noise as they were in mating season, which in turn had encouraged eels to come to the shallow water to look for prey. The eels were attracted to my headtorch as I waded out, but then I had to turn out the light and stand in the water in complete darkness to get my exposure. During this time, I felt eels brushing up against the outside of my waders, which, I can tell you, is a very alarming feeling.

I wished I could hear the familiar 'click' of my shutter closing so I could get out of the water, but instead I heard a 'bing' as my phone received an email. Interested to know who could be emailing me at 2am on a Tuesday morning, I performed the strange dance that is required when you are attempting to retrieve your phone from inside a set of waders.

It was an email from Nikon which read: "Get the most out of your camera". It left me standing there wondering, "What else do I need to do?!"

RICARDO BESSA/FOLIO ART

BBC

Sky at Night MAGAZINE

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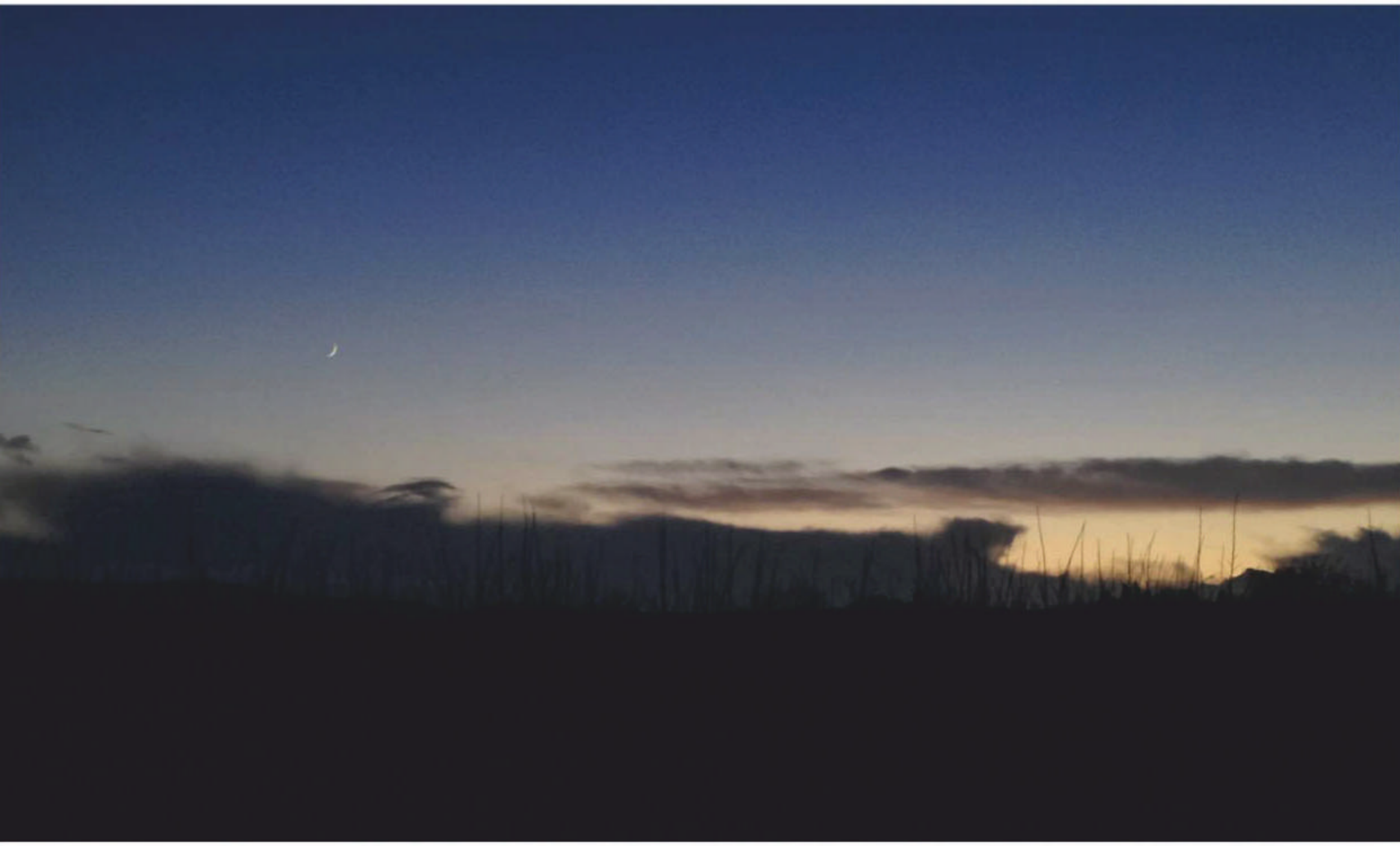
BBC Sky at Night MAGAZINE

With their increasingly sophisticated cameras, many smartphones are capable of taking great astrophotos

Capture the night sky with a SMARTPHONE

From point-and-shoot to pairing with your telescope, **Will Gater** explores how to get the best astro images with your smartphone

ISTOCK, WILL GATER



▲ **A good starting point is a simple nightscape featuring the Moon or bright planets like Venus and Jupiter**

You don't need the Hubble Space Telescope to see that some of the biggest recent strides in amateur astrophotography have happened when astronomers have seized upon innovations in consumer electronics. Take the advent of webcams. Never intended for use in astrophotography, they precipitated the birth of an entirely new field of lunar and planetary imaging by amateurs.

The same is happening today with camera-equipped smartphones. The phones themselves may not be a new phenomenon, but advances in the camera technology within them mean that huge numbers of people are carrying powerful tools for capturing the night sky in their pockets.

So how do you go about using your smartphone to get an astrophoto? There seems no better place to start than the very simplest type of shot, where you just whip the phone out of your pocket and snap a wide-field shot of a landscape with some celestial element. These 'nightscapes' make great targets for modern smartphones. They might include something like the Moon in deep twilight with silhouetted trees or buildings, or with the last reds, pinks and blues of the sunset sky fading away; or they could feature a bright planet (like Venus, Jupiter or even Mars) in a similar setting. You can snap the summer phenomenon of bright noctilucent clouds this way too.

Just as if you were using a DSLR for this type of shot, the key to taking a good smartphone nightscape is to keep the camera still. If you can't hold the phone motionless for the duration of the exposure, or when tapping the screen to fire the 'shutter', try to rest your arms or your phone against something solid like a wall or garden table. You can get mini tripods to hold a smartphone too. When choosing one, make sure it's sturdy enough and won't fall over or move in a breeze.

Before we go any further, it's worth saying that you shouldn't worry if your smartphone is a little long in the tooth. My own device is a 2013 model – ancient by industry standards – and even it can be ▸

"You may discover that your phone has features that are found in advanced, standalone cameras"

▸ encouraged to take a reasonable nightscape. When combined with other astronomical kit, older phones can produce really pleasing lunar and planetary images. It's my firm belief that in astrophotography the composition and originality of a shot is what will captivate the viewer long before they've examined the technical specs.

To give yourself the best chance of getting a good shot it's worth reading your phone's manual or searching for online guides on how to tweak the exposure and focus of your specific model's in-built camera. You may discover it has features you weren't aware of – which are sometimes found in more advanced, standalone cameras – that can be useful when shooting the night skies. One good example is the handy 'auto-exposure and auto-focus' lock function that is available on some devices. This lets you lock the exposure and focus point of the image so that you can adjust the composition while maintaining those settings. This can be useful if you're taking a nightscape of, say, the rising or setting Moon and want to keep the focus point locked on the lunar disc while you reframe to incorporate a foreground element.

Whatever your phone's spec, composition and originality are the fundamentals to get right

WILL GATER X 6, ISTOCK

Ever-better phone tech

Nowadays there are also smartphone astrophotography apps available that can take control of the device's camera and give you more on-screen control over the image settings. Some apps appear to stack images together as they are captured, creating something that's akin to a long exposure. This functionality can be used to capture images of prominent constellations and bright passes of the International Space Station.

What's perhaps most exciting for smartphone astrophotographers today is how quickly the technology is evolving. In particular, the recent demand for low-light imaging capabilities has prompted manufacturers to create devices with ever-more sensitive cameras, which – intentionally or

Angling for a great shot

Phone meets eyepiece: straight and steady is the key

One of the trickiest aspects of afocal smartphone astrophotography with a telescope is getting the phone's camera lined up to the eyepiece. If you don't, the edge of the eyepiece field of view can encroach into the shot and spoil the image or, at the least, the view will show 'vignetting', where the picture exhibits dark gradients. The trick to overcoming this is to, firstly, use an eyepiece with a relatively large exit pupil, as these tend to be more forgiving. If you have several eyepieces, experiment to see which gives the best results. Secondly, while ensuring that your smartphone camera lens is centred above the eyepiece aperture itself, also check that the device is held parallel to the top of the eyepiece and isn't at an angle.

▲ **Hold your phone centred and parallel to the top of the eyepiece**

Smartphone setups

Four ways to use your smartphone to capture night-sky images and video

Handheld

There are a fair few celestial targets and scenes that can be snapped by simply holding your camera up to the sky. These include strong displays of noctilucent clouds, twilight nightscapes featuring the Moon or a bright planet near the horizon, and even some of the more prominent atmospheric phenomena that astrophotographers sometimes go after, like a bright 22° ice halo around the Moon.

On a tripod

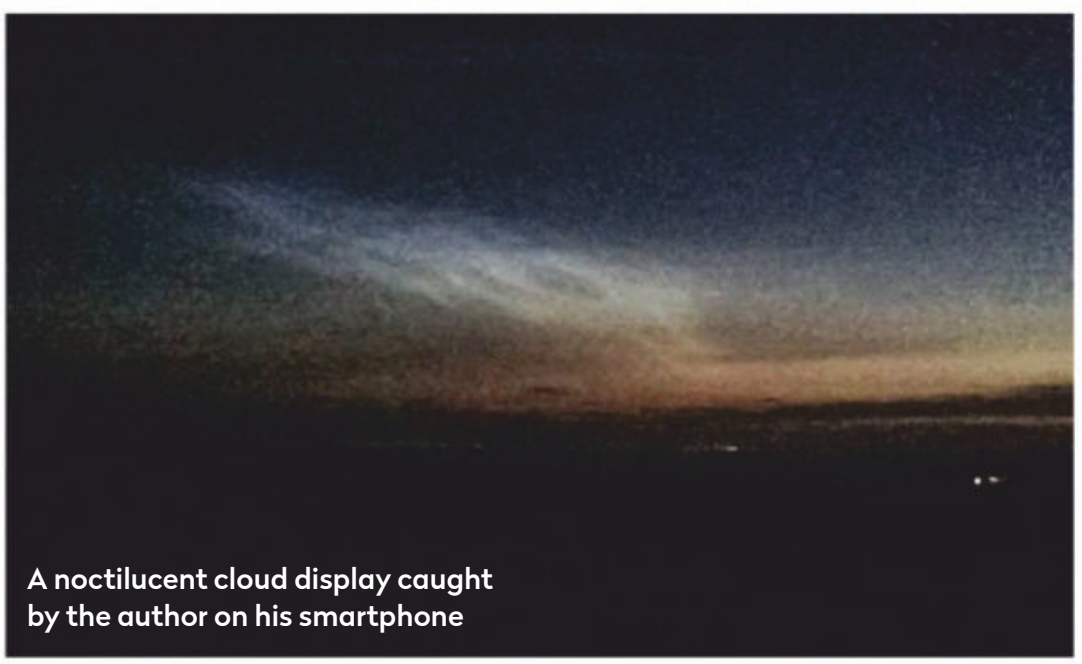
If you try to take longer exposures with your smartphone you will soon find that failing to hold the device still will almost always result in blurred images. Small, fixed, tripods for smartphones are available commercially and may help you get better results if you're shooting scenes that require exposures of a few seconds, such as nightscapes of bright constellations.

Afocal imaging with a telescope

Perhaps the most popular technique used in phone astrophotography today is to simply hold the lens of the smartphone over the eyepiece of a telescope which is pointed at the Moon or one of the bright planets. This 'afocal imaging' approach can produce superbly detailed pictures of the lunar surface as well as Jupiter and its moons, and the rings of Saturn.

Afocal imaging with binoculars

A sometimes overlooked form of smartphone astrophotography is afocal imaging with binoculars, instead of a telescope. Using binoculars can produce wider fields of view and can be a great way to get more detail on objects like the Moon (or planetary groupings and close approaches) while still being able to fit in some foreground scenery in a nightscape-style shot.



A noctilucent cloud display caught by the author on his smartphone

not – are now able to capture impressive celestial shots right out of the box. Indeed in the last year we've seen images of the bright Milky Way star fields, as well as the aurora, taken with one of the most advanced smartphones on the market. These devices currently cost more than a mid-range DSLR, of course, but it's likely that the camera and sensor technology in them will filter down to more basic phone models in the coming years.

There's no need to wait to get your hands on a top-of-the-range smartphone, however, if you want to image the Moon and bright planets and if you have a small telescope or a pair of binoculars. By holding a smartphone's camera up to the eyepiece of one of these instruments – a technique that astrophotographers call afocal imaging – you can grab detailed snaps of the cratered lunar landscape as well as the rings of Saturn, Jupiter and its four largest moons, and even the disc of the planet Venus during twilight.

Because binoculars magnify much less than a typical telescope and eyepiece combination, they can be particularly effective for afocal smartphone imaging of wide-field celestial events such as close approaches of the Moon and bright planets, as well as more frequent, but nonetheless captivating, ▸

An afocal image of the Moon taken by the author holding a smartphone up to a 26mm eyepiece of an 8-inch Schmidt-Cassegrain telescope

WILL GATER, ISTOCK, IAN GRIFFIN

PHOTO APPS

NightCap: www.nightcapcamera.com

Snapseed: https://snapseed.en.softonic.com

Adobe Lightroom CC: www.adobe.com/uk/products/photoshop-lightroom.html

PIPP: https://sites.google.com/site/astropipp

RegiStax: www.astronomie.be/registax

AutoStakkert!: www.autostakkert.com

Polishing up your astro images

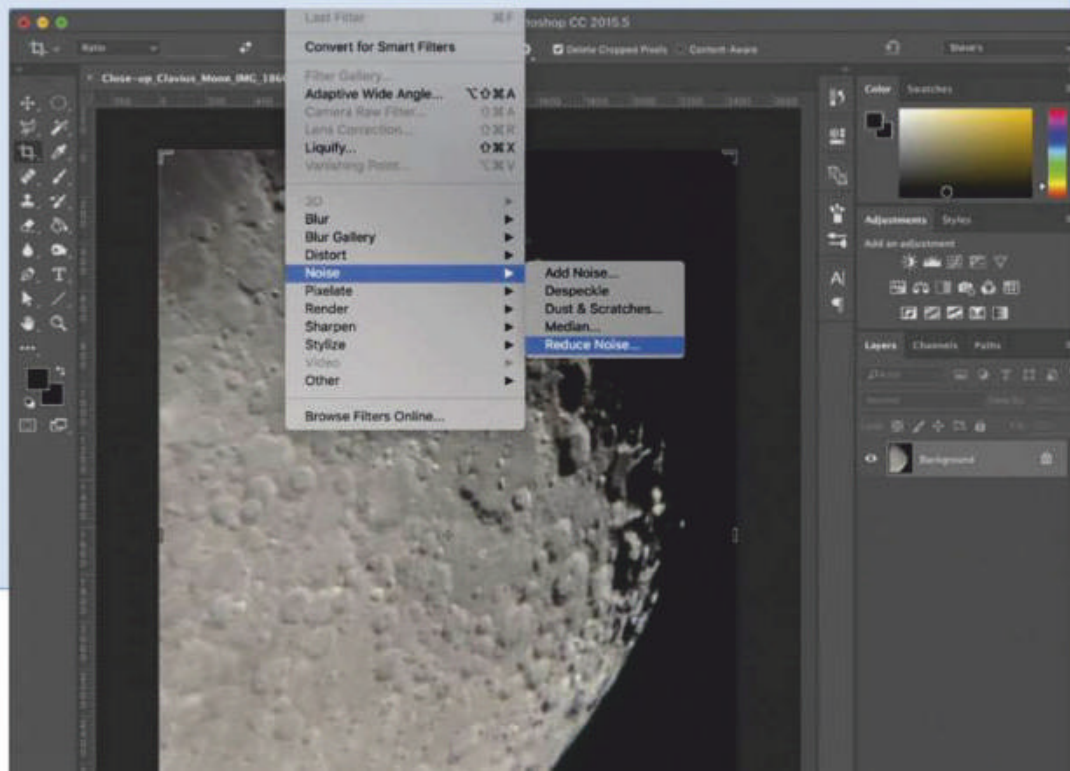
In-phone apps and advanced programs to hone your smartphone shots

In astrophotography the image captured by the camera is rarely the final version and you'll no doubt want to tweak pictures you've snapped with your smartphone too. You can of course bring your shots into your chosen image editor on your computer for sharpening, levels and curves adjustments and colour balancing, but there are also apps such as Snapseed and Adobe Lightroom CC which let you make tweaks on your device.

For more advanced work such as noise reduction – often needed with smartphone images – a program like Photoshop or GIMP on your computer is the tool to go for. If you intend to make a mosaic of the lunar surface, using multiple overlapping shots captured with your phone looking down the eyepiece of a scope, you'll need a layers-based image editor like this.

To create such a lunar mosaic, first import all of the phone images into a new file as separate layers. Drag each image around, repositioning and rotating them where necessary so that they are aligned. Temporarily setting the 'blend mode' to 'difference' between individual layers can sometimes help you hone in on the correct orientation. Erase any hard edges or frame boundaries using a soft-edged eraser tool and then 'flatten' the image to create a final picture that can be adjusted further if needed.

When imaging the bright planets afocally with a phone and telescope, you may get better results if you capture a short video of the planet through the eyepiece. This video file can be brought into the software PIPP and turned into an AVI file. This AVI video file can then be analysed and processed by software such as RegiStax or AutoStakkert! to create a sharper, more detailed, final image.



► **Photoshop is one of the most versatile programs for enhancing your smartphone pictures**

► This incredible image of the Milky Way was taken by Ian Griffin in New Zealand with his Huawei P20 Pro smartphone mounted on a tripod (30-second exposure at f1.8, ISO 3200)

► scenes like the crescent Moon at twilight or the full Moon rising over a horizon.

Get a grip

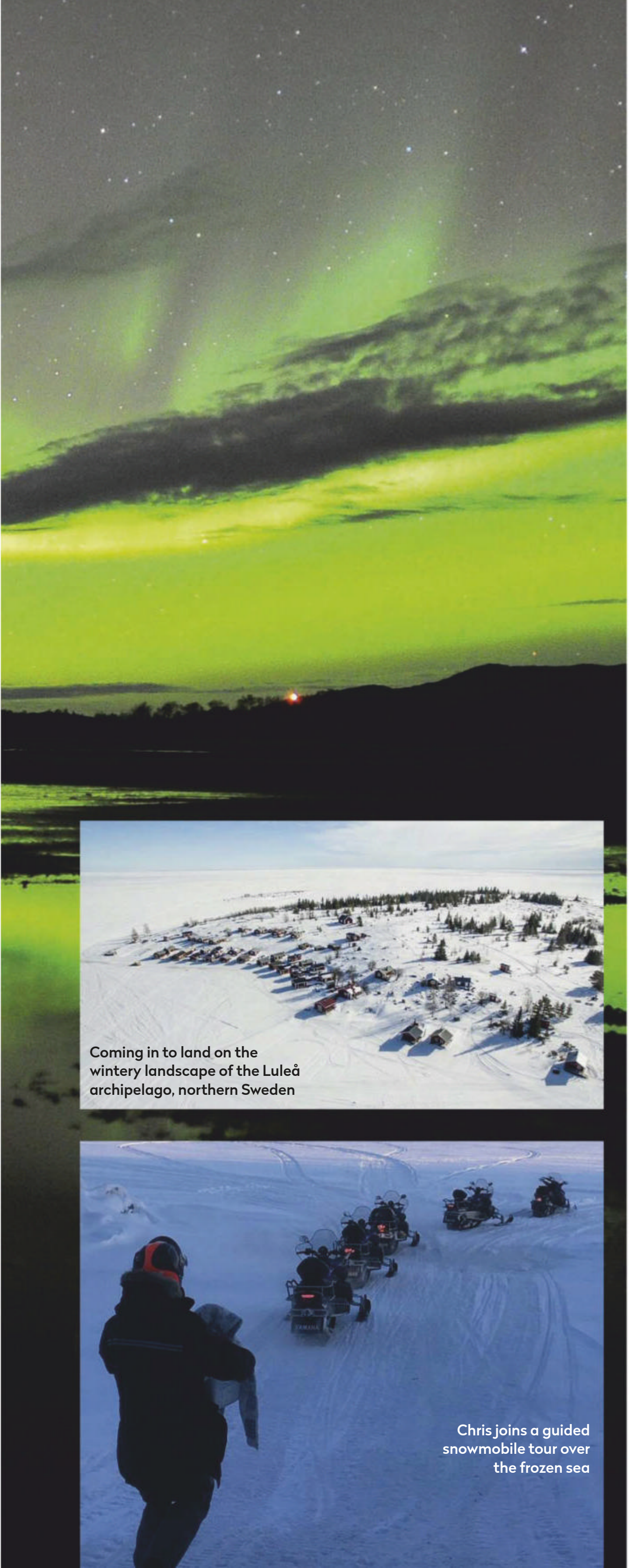
The challenge with afocal imaging is that you need to line up the camera carefully to the eyepiece, regardless of whether it's on a telescope or a pair of binoculars. Take great care not to scrape the phone against the eyepiece glass when afocal imaging as that may cause damage to your equipment. It is possible to buy commercial smartphone 'cradles' that can make this task much easier by clamping to the eyepiece while holding the phone tightly above so it can be aligned over the lens. If you want to find out how to make your own, turn to page 68. Make sure that the smartphone is securely attached and won't cause the eyepiece or phone to slip and fall from the telescope while you're imaging.

With your smartphone fixed firmly in place, new afocal imaging opportunities will then be opened up to you. For example, you can create mosaics of the lunar disc by snapping multiple shots of slightly different but overlapping areas of the Moon and combining them in image editing software later. And you can even carry out a basic form of high-frame-rate imaging of the bright planets by recording video that you can then process and analyse in software to extract the sharpest frames for stacking. What's more, these techniques – and other skills that you can learn from smartphone astrophotography, like composition and processing – are the same ones you'll need if you decide to move on to more advanced astronomical equipment and cameras. So if you've been pondering how to take your first steps in astro imaging, the answer may be: with the smartphone right in front of you.

Will Gater is an astronomy writer and presenter. Follow him on Twitter at @willgater or visit willgater.com

Adventures in the AURORA ZONE

Dog sledding, a bedroom made of ice and dinner on a frozen sea: **Chris Bramley**'s search for the aurora in Swedish Lapland delivered far more adventure than he bargained for



◄ **A good chance of catching the aurora is just one of the highlights of Swedish Lapland**

Coming in to land on the wintery landscape of the Luleå archipelago, northern Sweden

Chris joins a guided snowmobile tour over the frozen sea

Out in the magical frozen landscape of Swedish Lapland with our cameras and an experienced photography guide, I felt that this was the best opportunity I'd had so far to witness the aurora. And I wasn't wrong. Less than 10 minutes later, a misty grey-white tendril appeared in the night sky above the horizon. There they were – the Northern Lights!

Their defined ray shape changed slowly, bending, undulating and twirling until it took on an entirely different form from the diagonal line that had first appeared. In next to no time it had morphed again, this time into a wave that was then joined by what looked like a forest fire burning green. What an experience, and what a setting to witness it in.

Aurora hunters know that to maximise your chances of seeing the Northern Lights you need to get as close to the Arctic Circle as possible. High in the sky above this Arctic region, Earth's magnetic field funnels charged particles streaming from the Sun along magnetic field lines, down into the atmosphere, creating the aurora spectacle in a ring centred on the magnetic north pole. And here I was, in this auroral zone, close to the town of Kiruna in Swedish Lapland, hoping to have a ringside seat.

Hunting the lights on ice

I'd flown into northern Sweden from the UK a few days earlier and it was like stepping into a wonderland. On the descent to Luleå, Swedish Lapland's biggest city, we had passed over a wintery landscape of dark forest broken with patches of snowy white. It looked cold, and enchanting. Coming face to face with that cold for the first time was a shock: the temperature was -20°C, easily the coldest environment I'd experienced. And, not for the last time, I felt profoundly grateful for my decent thermals.

It wasn't long before my chance came to get immersed in the adventure of this unique, high-altitude environment. After dark, we were to be taken on a guided aurora hideaway dinner organised by the Pine Bay Lodge, a cosy, traditionally red-painted hotel half an hour's drive north of Luleå. On the frozen, snow-covered lake outside, a snowmobile and two wooden carriages were waiting. It was going to be a short drive to our destination, and there were quilts to keep us warm on the way.

Off we sped, along the shoreline of the frozen lake, sheltered from the chilling wind beneath our blankets. We passed prettily lit houses and white-robed trees until we were out in the Gulf of Bothnia, the open sea dotted with islands and a wide-open sky above. Just in front of us in this otherworldly setting was a tiny ►

VISIT LAPLAND, CHRIS BRAMLEY X 2

◄ Giving the huskies a half-way break during an exhilarating two-hour sled ride

▼ A warm spot for 'fika' after sledding – some consolation after an aurora no-show

► shepherd's hut circled with flickering lights. Inside, a log burner kept it toasty and warm as we tucked into the meal cooked on the fire right outside.

Cloud cover meant that there was no aurora to see that night, but as we returned across the spellbinding snowy landscape, a strange light effect appeared and disappeared at intervals – light pillars. Stretching up into the sky, above the treeline, were vertical shafts of light created by distant car headlights reflecting off flat ice crystals hanging in the frozen air. Settling down on the sofa next to the roaring fire in the Pine Bay Lodge's lounge, there was a chance to reflect, and the evening had been no less magical without the Northern Lights.

Pine Bay Lodge and its sister hotel, Brändön Lodge, both run guided trips by day. From Brändön Lodge, where accommodation is in cosy winter cabins set around a luxuriously appointed communal lodge, there are several ways to explore the frozen sea and islands of the Luleå archipelago: by hovercraft, dogsled, snowmobile or snowshoe. Our two-hour snowmobile trip out among the islands was utterly exhilarating. Following our guide, woodsman Tommy Holmberg, driving our own snowmobiles out on the flat, frozen expanse of sea ice, dressed in the insulated bodysuits, thick gloves, snow boots and helmets provided by the hotel, made it seem more like we were astronauts exploring an alien lunar landscape.

Time to mush

An altogether more Earth-like experience is dog sledding: there can be little doubt what planet you

CHRIS BRAMLEY X 5, GRAEME RICHARDSON X 2

Pine Bay Lodge activities include aurora trips, nature tours, dining and dog sledding

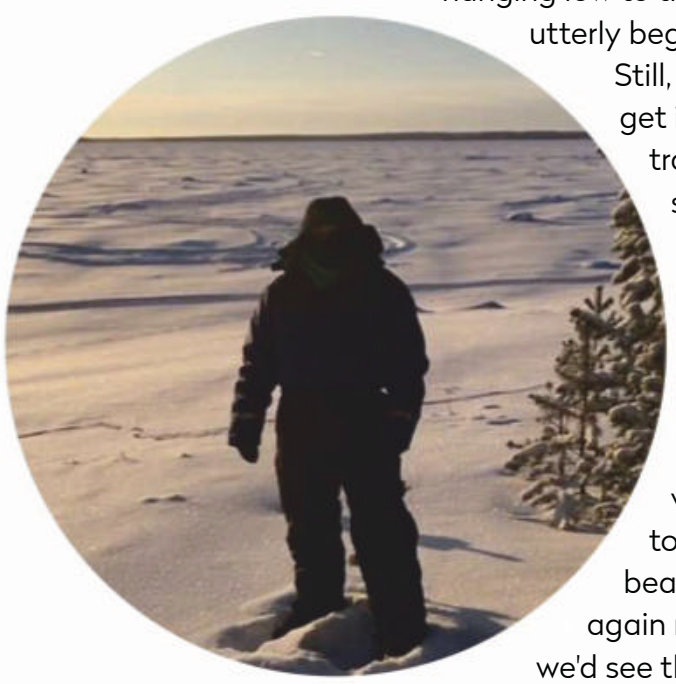
Sister hotel Brändön Lodge, half an hour south, also runs guided trips across the ice

▲ **A two-hour drive north of Luleå through reindeer country brings Chris to the Arctic Circle**

are on when your means of propulsion is a pack of 10 huskies! Again, warm outerwear was available at the dog sledding centre and we pulled on the bodysuits and extra gloves quickly so we could help get the dogs in their harnesses.

The sled ride itself was a revelation. After all the howling and panting (the dogs, not us) and the excitement of preparing to leave, once we were away and the sled was gliding gracefully through the trees, a serene peace set in. Intent on stretching their legs and pulling the sled, the only sound to come from the husky pack now was panting. The sky was clear and, as it was around 3pm, it began to get dark. Before night fell, a beautiful light descended: overhead it turned a deep azure blue, which was reflected by the snow-clad landscape; a truly all-round magical colour. Between the trees, glimpses of the Moon hanging low to the horizon completed this utterly beguiling experience.

▼ **Not an astronaut, but Chris in the essential kit for the weather – all luckily provided by the hotel**



Still, it was no less welcoming to get into the warmth of the traditional hut at the dog sledding centre and sit with a coffee by the fire. After the adventure of sledding, this Swedish tradition of 'fika' – taking time to relax and warm up over a hot drink and a pastry – was very welcome. It also served to make the news much more bearable that cloud cover again meant it was unlikely that we'd see the aurora for another night.

The absence of the Northern Lights did however make it possible to experience the city of Luleå free from guilt at missing out on a display. Situated on the edge of the Gulf of Bothnia, it was a welcome surprise to experience sophisticated urban living so close to the wild, forested interior and the otherworldly, almost lunar landscape of the frozen sea ice. The city is rightly proud of its restaurants, several of which have made it into Scandinavia's top dining handbook, *The White Guide*.

From freezer to feast

The food here is world-class, the gifted chefs using local ingredients to full effect. Highlights include the reindeer tartare, almond crisps and pomegranate pips dusted with chanterelle mushrooms and juniper at Bistro Norrland; a mixed grill of reindeer, moose, wild boar and red deer with celeriac and baked apple puree and shiitake jus at CG's; and a cloudberry sorbet with vanilla ice cream, white chocolate and oat crisp at Hemma Gastronome. Savouring the tart and sweet flavour of the cloudberry, a raspberry-shaped yellow berry found only in cold climates, I marvelled at the quality of food available at temperatures 20° below freezing.

The next morning it was time to say goodbye to Luleå and head north to Kiruna. It's possible to make this four-hour journey into the Arctic on the train, but we drove, giving the opportunity to stop at the Arctic Circle. It's a dramatic route, with stunning scenery, and on a clear winter's day, the low Sun lends a beautiful pink light and long shadows to the forested hilltops and wide river valleys.

The route was well cleared of snow and traffic was ▸

▲ **The Icehotel, 200km north of the Arctic Circle: artfully sculpted luxury and a good chance of an aurora display**

Danger: Thin Ice – one of the unique suites carved by ice artists

ASAF KLIGER, FRANZISKA AGRAWAL/ASAF KLIGER, CHRIS BRAMLEY, ISTOCK

▸ light, but even so, driving in such low temperatures takes care, attention and a set of winter tyres with metal studs to provide extra grip. Reindeer are a common sight and drivers must be ready to stop for any crossing the road. To alert drivers to roaming herds, the local Sami people who own the animals fix black bin liners to the posts that line the main roads.

Two hours into the journey, we reached the Arctic Circle, the great line of latitude marked by a large sign and an impressive information display. It explained that at the winter solstice the Arctic Circle represents the northernmost point at which the Sun is just visible at midday. Further north from here was the land where the Sun stayed below the horizon for weeks in midwinter.

The Sun was just setting when we reached our destination two hours later, the Icehotel. This unique resort, a short distance outside Kiruna, is centred on two hotels constructed entirely from the snow and ice taken from the Torne River next to which they sit. One of the buildings is seasonal and in spring melts back into the river. The other is year-round, built in a stone and earth shell to preserve the cold in the warmer seasons. The whole place has a pristine feeling. Perhaps it's the exceptionally clear block of river ice all around it. Inside both hotels, the rooms are kept at a constant -5°C, and with temperatures outside being 15° lower than that, it felt positively warm walking through the doors. In the tall, church-like structure there's a soothing quiet, the snow and ice walls cutting out sounds very effectively.

It's not just the ice that makes this a special place to sleep, the Icehotel's rooms are themselves works of art: each is a distinctive ice sculpture, a theatre set with a bed. During the day the rooms are open to all guests to visit, so those who choose warm

Swedish Lapland, the guided way

How to book your own adventure in Swedish Lapland

The Arctic in winter is an environment that should be treated with respect, and an experienced local guide can help you get the most out of it, turning the risk of exposure in the extreme climate into something utterly exhilarating. A guide will know whether an extra pair of gloves is needed, or a pair of boots is suitable for the conditions. They'll also know the local weather patterns and give advance warning of snow showers or high winds.

Visit Lapland
Visit Lapland help those planning an Arctic adventure to put together their own programme of guided activities from across the Lapland region of Sweden, Norway and Finland.

To find and book Northern Lights photography evenings, Icehotel tours, dog sledding, hovercraft tours and Sami or snowmobiling experiences, visit **www.visitlapland.com**.

Off the Map Travel
For those looking for a luxury, tailor-made Northern Lights holiday, specialist travel advisors at Off the Map Travel can help. Visit **www.offthemap.travel**, call 0800 566 8901 or email info@offthemap.travel.

Flights
Flights to Swedish Lapland's two main airports, Luleå and Kiruna, are operated by SAS and Norwegian. They connect in Stockholm, which can be reached from many UK airports.

► Swedish Lapland, the Arctic north of Sweden: Luleå, Pine Bay Lodge and Brändön Lodge are shown in the south east; Kiruna and the nearby Icehotel are in the north

▼ Chris was surprised by how quickly the aurora appeared, but managed to capture this shot

Chris Bramley has over a decade's experience in science journalism, and has edited *BBC Sky at Night Magazine* since 2011

accommodation in chalets can take them in too. It is enchanting to walk through this frozen art gallery, taking in the different works.

Room with a view

Each year, different artists are invited to decorate a room. On this visit, one room was carved to look like an underwater aquarium, complete with friendly sharks and a shoal of fish. Another had the bed on a pontoon over what appeared to be cracked ice below. And one was sculpted to look like a Victorian library, complete with book-lined shelves and armchairs hewn from ice. It was truly impressive to see what can be done with frozen water, a chainsaw and chisels.

By now our final night in the aurora zone had arrived and, after an exceptional meal in the Icehotel's warm, fine dining restaurant, it was time to don the winter layers provided by the hotel for our guided aurora hunt. We were met in the lobby area by our guide from aurora tour experts Lights over Lapland, senior photographer Chris Hodgson. All our photography equipment was provided and we were taken carefully through how to set up the tripod, how to adjust the capture settings on the DSLR cameras, and how to frame and manually focus the shots in the dark. Once we were all comfortable with the camera controls, we jumped in the minibus and headed out to a local spot known for its clear horizons.

The forecast was for a clear night and excitement was high as we reached our destination. A quick glance up confirmed it: the stars were out! We set up our tripods and cameras in the snow a short distance from a roaring camp fire and waited. Just a short time later, an aurora display developed that put the cherry on the cake of this adventurous Swedish trip. We clicked away, our guide Chris on hand to help with focusing or adjusting the settings to best capture the shifting levels of light. It was a captivating way to capture the aurora, the deep blue sky patterned with tendrils of faint green above, white snow-covered landscape below, and the yellow glow of a camp fire off in the distance.

Chris travelled to Sweden with Visit Lapland and Swedish Lapland

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BBC Sky at Night MAGAZINE

16-PAGE CENTRE PULLOUT

The Sky Guide

MARCH 2019

THE BIG SOLAR SYSTEM LINE-UP

Venus, Saturn, Jupiter and the Moon aligned

DEEP-SKY TOUR

GALACTIC GEMS OF COMA BERENICES & CANES VENATICI

SKY GUIDE CHALLENGE

CAN YOU FIND THE ELUSIVE PUP STAR?

PETE LAWRENCE

About the writers

Astronomy expert **Pete Lawrence** is a skilled astro imager and a presenter on *The Sky at Night* monthly on BBC Four

Stephen Tonkin is a binocular observer. Find his tour of the best sights for both eyes on page 54

Red light friendly

To preserve your night vision, this Sky Guide can be read using a red light under dark skies

Don't miss...

- ✦ Mars near the Pleiades
- ✦ An equinox opportunity to see the aurora
- ✦ Cassini's Moon Maiden comes into view
- ✦ The eerie glow of the zodiacal light

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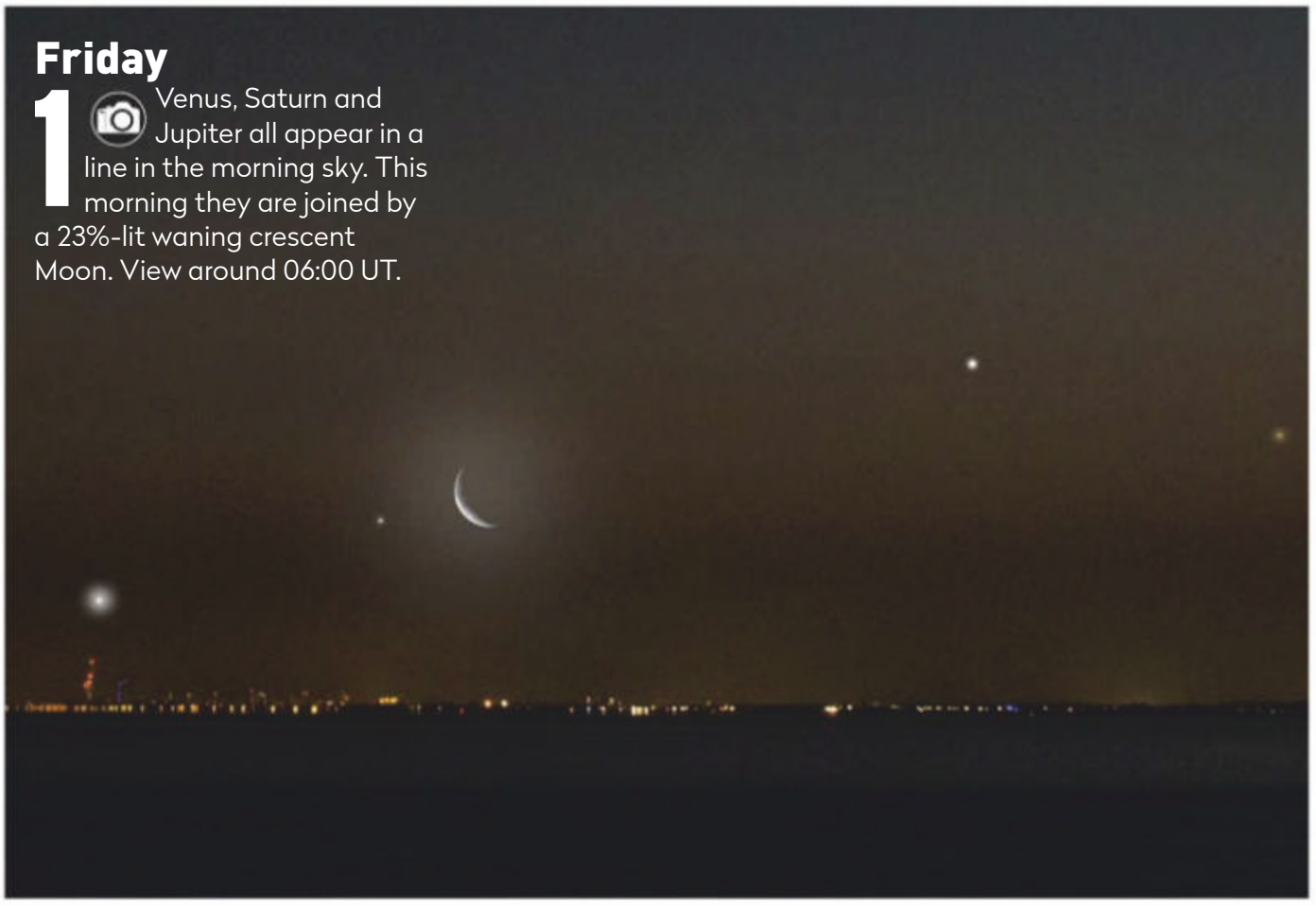
For weekly updates on what to look out for in the night sky, sign up to our newsletter: **www.skyatnightmagazine.com/iframe/newsletter-signup**

MARCH HIGHLIGHTS

Your guide to the night sky this month



Friday

1 Venus, Saturn and Jupiter all appear in a line in the morning sky. This morning they are joined by a 23%-lit waning crescent Moon. View around 06:00 UT.

Saturday

2 This morning a now 16%-lit waning crescent Moon lies 6.8° to the west of mag. -4.0 Venus.

Tuesday

5 The Moon being out of the way makes this is a great time to try to see the faint conical glow of the zodiacal light towards the west. Typically, if visible, it appears in a 90-minute window starting 90 minutes after sunset.

◀ Monday

11 Catch a telescopic view of Jupiter around 04:30 UT and you'll see Ganymede and Io close to the planet's northeast limb.

This evening's 23%-lit waxing crescent Moon lies 6° south of mag. +1.3 Mars.

Wednesday

13 The clair obscur effects known as the Lunar X and V reach peak visibility at 16:45 UT, under daylight conditions.

Monday

18 Ganymede's giant shadow starts to cross Jupiter's disc from 04:00 UT. Ganymede and Europa appear close to Jupiter's east limb with Io out to the west.

◀ Wednesday

20 At 21:58 UT the centre of the Sun's disc crosses the celestial equator moving north, a point known as the Northern Hemisphere's spring, or vernal, equinox. The length of daylight is expanding at its fastest rate for the year today.

Wednesday

27 Jupiter appears 1.1° south of the a 60%-lit waning gibbous Moon as they both rise after 01:30 UT.

Later there's a lovely double eclipse of the moons Io and Europa. Watch them disappear into Jupiter's shadow just after 02:30 UT.

Friday

29 This morning a 40%-lit waning crescent Moon lies 53 arcminutes from Saturn.

At 02:30 UT Galilean moons Europa and Ganymede appear close to Jupiter's western limb.

PETE LAWRENCE X 7

Sunday 3

The beautiful morning show continues with a much thinner 9%-lit waning crescent Moon lying 4.7° to the east of Venus.

◀ Monday 4

With no Moon to contend with, this is an ideal time to try for this month's Deep-Sky Tour objects (see page 56). This month we're looking at some striking galaxies on the border of Coma Berenices and Canes Venatici.

Thursday 7

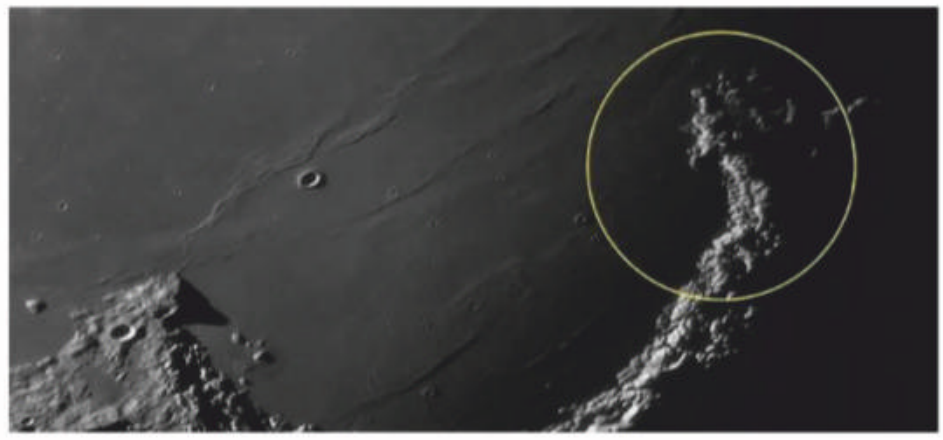
Look towards the west immediately after sunset and see whether you can pick out the slender shape of a 1%-lit waxing lunar crescent. Be quick, though, because it's only up for 40 minutes following sunset. Take care not to look until the Sun has disappeared.

Friday 8

This month's Moonwatch target (see page 52), the 88km crater Atlas, is right on the Moon's morning terminator this evening.

Sunday ▶ 17

The clair obscur effect known as Cassini's Moon Maiden will be visible in the run-up to midnight. Turn your scope to Promontorium Heraclides, which marks the southern extreme of Sinus Iridum. It needs to be viewed inverted with south up.



Thursday 21

Today's full Moon, which occurs at 01:43 UT, is the third and final perigee full Moon (supermoon) of 2019, lunar perigee having been reached at 19:47 UT on 19 March.

◀ Tuesday 26

Look south in the early hours to see mag. -2.1 Jupiter, a 69%-lit waning gibbous Moon and the mag. +1.0 red supergiant star Antares (Alpha (α) Scorpii) forming an attractive triangle.

Sunday 31

Look out this evening for Mars, 3.1° to the south of the Pleiades open cluster.

British summer time begins.

Family stargazing – M44 Cluster

The Beehive Cluster, M44, is well placed in the dark, moonless, early evening skies at the start of March and a great target to find through star-hopping. First identify twin stars Castor and Pollux in Gemini. Now find Regulus (Alpha (α) Leonis) in Leo, at the bottom of the backward question mark known as the Sickle. Now imagine a line between the upper twin star Castor and Regulus. Look below the line's mid-point using binoculars or a low-power telescope to find (although it may take a few goes) the beautiful Beehive.

www.bbc.co.uk/cbeebies/shows/stargazing

NEED TO KNOW

The terms and symbols used in The Sky Guide

Universal time (UT) and British Summer Time (BST)

Universal Time (UT) is the standard time used by astronomers around the world. British Summer Time (BST) is one hour ahead of UT.

RA (Right ascension) and dec. (declination)

These coordinates are the night sky's equivalent of longitude and latitude, describing where an object is on the celestial 'globe'.

Family friendly
Objects marked with this icon are perfect for showing to children

Naked eye
Allow 20 minutes for your eyes to become dark-adapted

Photo opp
Use a CCD, planetary camera or standard DSLR

Binoculars
10x50 recommended

Small/ medium scope
Reflector/SCT under 6 inches, refractor under 4 inches

Large scope
Reflector/SCT over 6 inches, refractor over 4 inches

GETTING STARTED IN ASTRONOMY

If you're new to astronomy, you'll find two essential reads on our website. Visit http://bit.ly/10_Lessons for our 10-step guide to getting started and http://bit.ly/First_Tel for advice on choosing a scope.

THE BIG THREE

The three top sights to observe or image this month

DON'T MISS

Morning LINE-UP

BEST TIME TO SEE: 1–3 March at 06:00 UT and 27–30 March from 01:30 UT until dawn

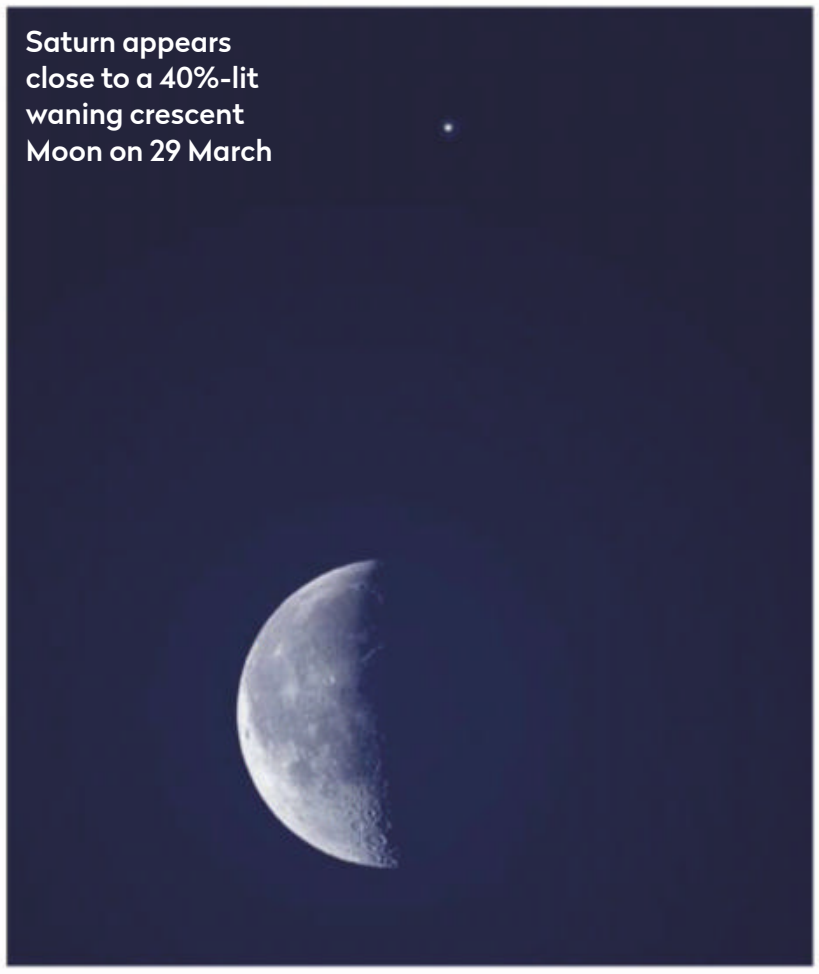
Recent months have shown some spectacular Solar System line-ups in the east-southeast and southern part of the morning sky before sunrise. This trend continues into March. On 1 March just before 06:00 UT it's possible to see (in order from the Sun) mag. -4.0 Venus, mag. +1.0 Saturn, a 23%-lit waning crescent Moon and mag. -1.9 Jupiter. In addition, the mag. +1.0 red supergiant star Antares (Alpha (α) Scorpii), can be seen close to the meridian. Antares appears 13° west and slightly south of Jupiter.

The following morning on 2 March, the now 16%-lit Moon will have slipped further east to lie between Saturn and Venus. On the morning of 3 March, the Moon's phase will have decreased to 9%. Its position will also have deteriorated, placing it 4.5° east and slightly south of Venus. In order to see the Moon's crescent on 3 March you'll have to give it time to rise above the murk close to the horizon. This will be something of a balancing act because the Sun rises 60 minutes after the Moon.

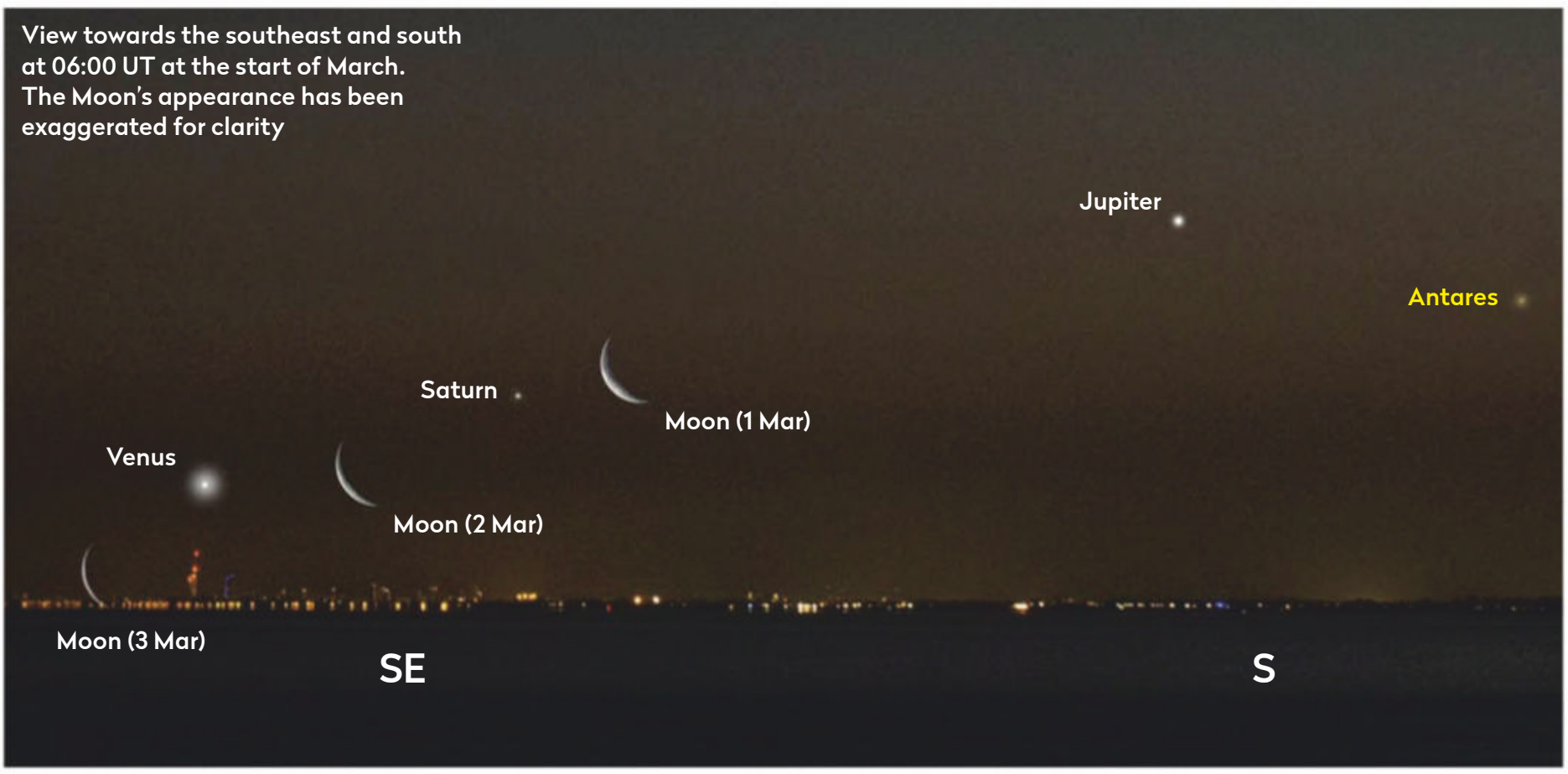
The angle the ecliptic makes with the UK's eastern horizon is shallow during spring and this keeps the altitude of the planets low. It's especially noticeable with Venus which is currently moving slowly back towards the Sun and nudging gradually south of the ecliptic as it goes. At the start of March, Venus rises 90 minutes before sunrise. By the end of the month this figure decreases to just 50 minutes, making this blazing planet harder to see at the end of the month.

As we approach the end of March, even though Venus has become harder to see, the Moon manages to liven things up once more. On the morning of 27 March, look out for a 60%-lit gibbous Moon rising just after 01:30 UT above the southeast horizon. As the Moon's disc slowly gains altitude, look immediately to the south of it. Here you should be able to see mag. -2.1 Jupiter. Centre-to-centre, Jupiter and the Moon will appear 1.1° apart at this time. As the apparent diameter of the Moon is around 0.5°, this will mean that Jupiter appears 0.8° from the Moon's southern limb as they rise. Over the rest of the morning the separation increases as the Moon shifts slowly east.

Then on 29 March, it's Saturn's turn for a close encounter with the Moon. As the dawn twilight takes hold around 04:20 UT, centre-to-centre both planets and the 40%-lit waning crescent Moon appear just 0.9° apart.



Saturn appears close to a 40%-lit waning crescent Moon on 29 March



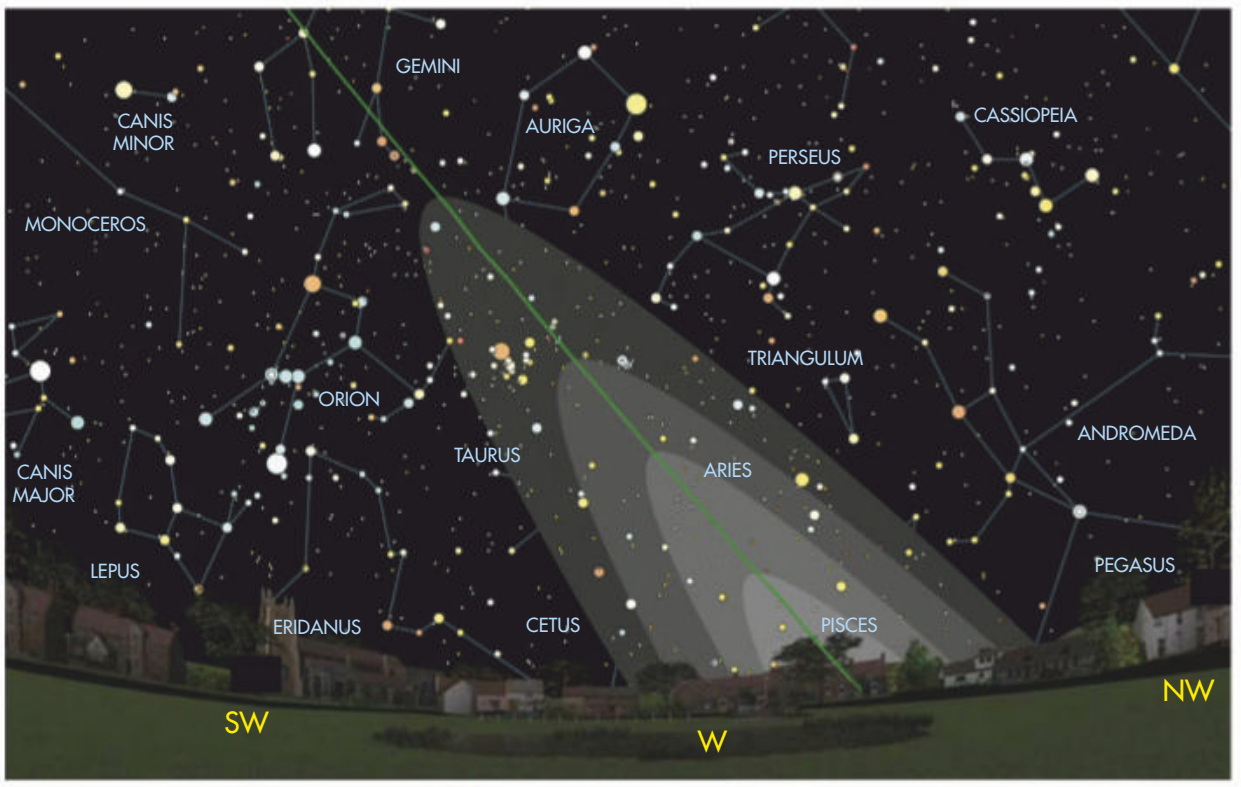
View towards the southeast and south at 06:00 UT at the start of March. The Moon's appearance has been exaggerated for clarity

PETE LAWRENCE X 4

Zodiacal light

BEST TIME TO SEE: 1–7 March and 24–31 March

▼ **Approximate location of the zodical light during March 2019. The phenomenon will be optimally placed toward the end of the month. The stars are shown for 9pm mid-month**



The equinoxes provide the best opportunity for spotting a delicate phenomenon known as the zodiacal light. This is quite challenging to see and is normally associated with very dark sky locations outside of the UK. However, with vigilance it can be seen from British soil and in 2018 there were a number of UK-based sightings reported.

The zodiacal light is produced when dust along the plane of the ecliptic scatters sunlight. The result is a white glow stretching along the ecliptic from the Sun. It appears widest close to the horizon, narrowing to a blunt point.

There are several hurdles to overcome before you can positively report you've seen it. We've already mentioned dark skies, so observing when the Moon is out of the way is essential. Fortunately, the new Moon on 6 March makes the start of the month a good prospect. Then, of course, there's the weather. Clear, clean air is optimal. Timing is important too and the zodiacal light is typically visible in a 90-minute window beginning 90 minutes after sunset.

The final hurdle is expectation. The zodiacal light typically appears with a rounded, conical shape tilted to the western horizon, its central axis aligned with the ecliptic. It's large and has a low surface brightness which is why it's easily lost in less-than-dark or hazy conditions. If you don't set your expectation levels correctly it's possible to look right at it and not even see it!

The zodiacal light is a good target for the naked eye because of its large size. Another way to detect its presence is to use a camera fitted with a wide-angle lens. With the camera centred on the western horizon, try taking a time-lapse sequence, capturing an image every five minutes or so. When played back, if the zodiacal light is present, it should be fairly obvious to see.

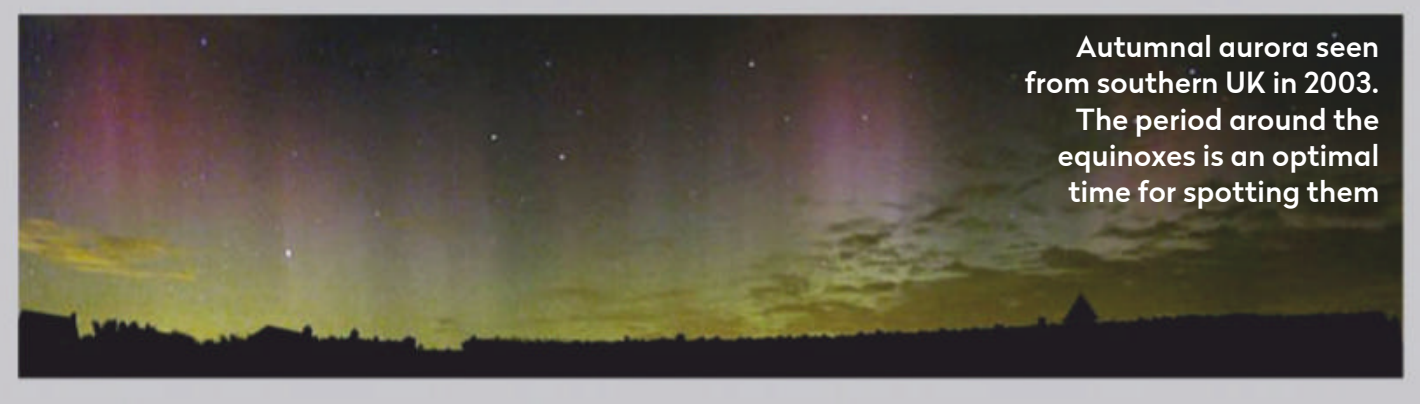
Equinox aurora

BEST TIME TO SEE: 1–7 March and 24–31 March, equinox is on 20 March

The aurora borealis has a prominent place on many people's bucket lists. Grabbing a view of the Northern Lights normally means planning a trip north to locations which lie close to, or under, the so-called 'auroral oval'. This is a region where the aurora normally appears, a band around Earth's northern geomagnetic pole.

The appearance of the aurora is the result of a complex interaction between the Sun and Earth's magnetic field. The Earth has a north-pointing field but the field contained in the solar wind that reaches Earth changes in polarity over time. Sometimes it's strongly southerly and sometimes strongly northerly. When there are south-pointing fields present in the solar wind, these can partially cancel portions of Earth's magnetic field, opening 'cracks' which ultimately help drive auroral displays.

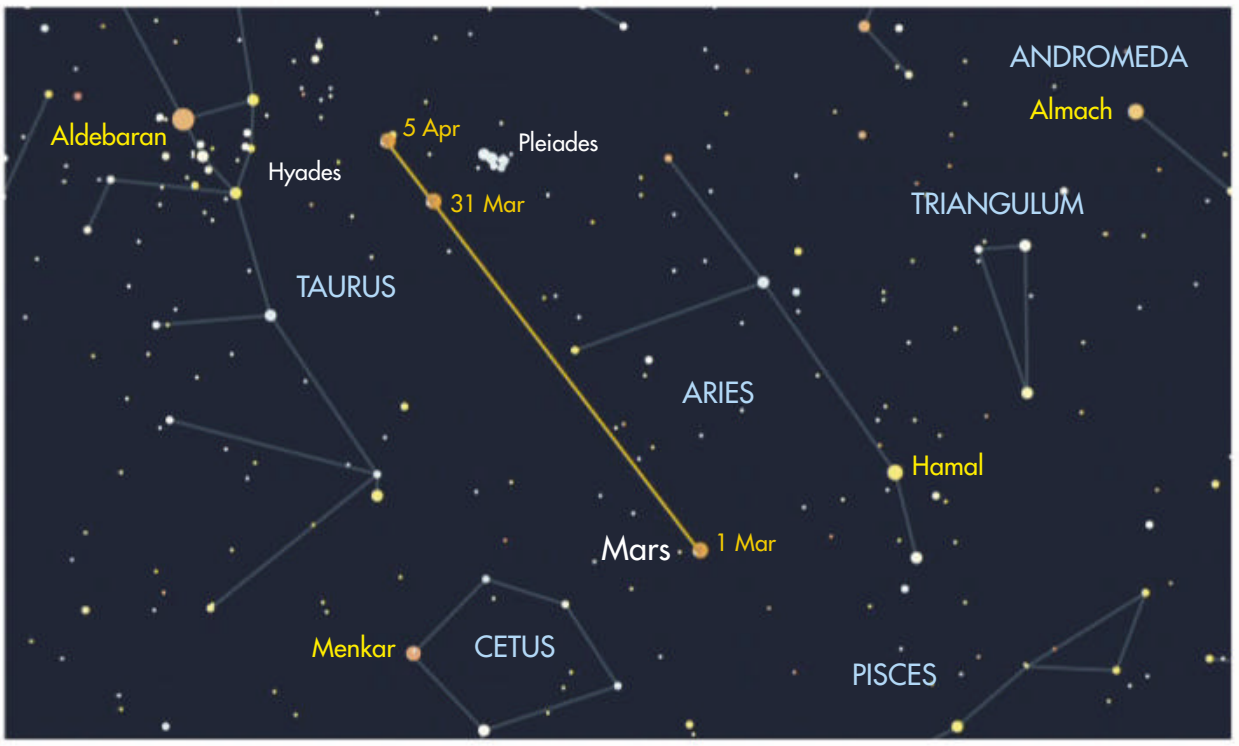
Known as the Russell-McPherron effect, the weakening of our planetary field is at its greatest during the period around the March equinox. This is when geomagnetic activity reaches a peak for the year and consequently is the best time to keep a look out for the aurora. If you fancy having a go at observing it, turn to page 74 to find out the best way to go.



Autumnal aurora seen from southern UK in 2003. The period around the equinoxes is an optimal time for spotting them

THE PLANETS

Our celestial neighbourhood in March



▲ **Mars tracks from Aries to Taurus this month, passing south of the Pleiades open cluster**

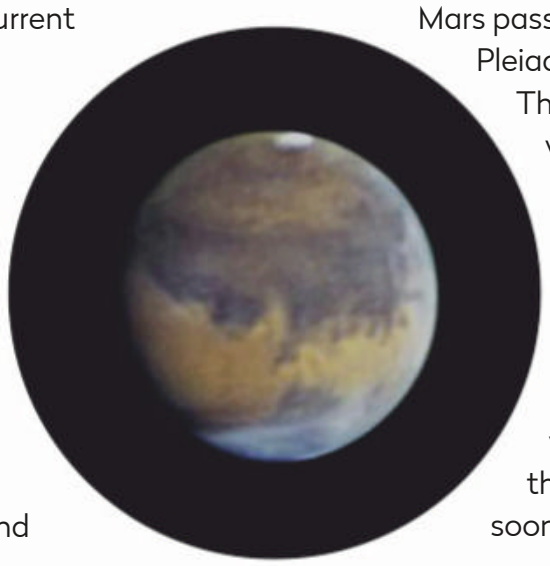
PICK OF THE MONTH

Mars

Best time to see: 1 March, 19:30 UT
Altitude: 35°
Location: Aries
Direction: South-southwest
Features: Polar caps, surface markings, phase
Recommended equipment: 3-inch or larger

PETE LAWRENCE X 3

Telescopically the planet Mars is well past its best for its current period of visibility, appearing rather small through the eyepiece and relatively dim compared to its heyday at opposition in July of 2018. On 1 March it shines at mag. +1.2 and presents a 5 arcsecond disc when viewed using a telescope. This shrinks to a tiny 4 arcseconds by the end of the month, a size that really makes it quite hard to see much detail at all. The planet will have dimmed further by 31 March too, dropping to mag. +1.5.



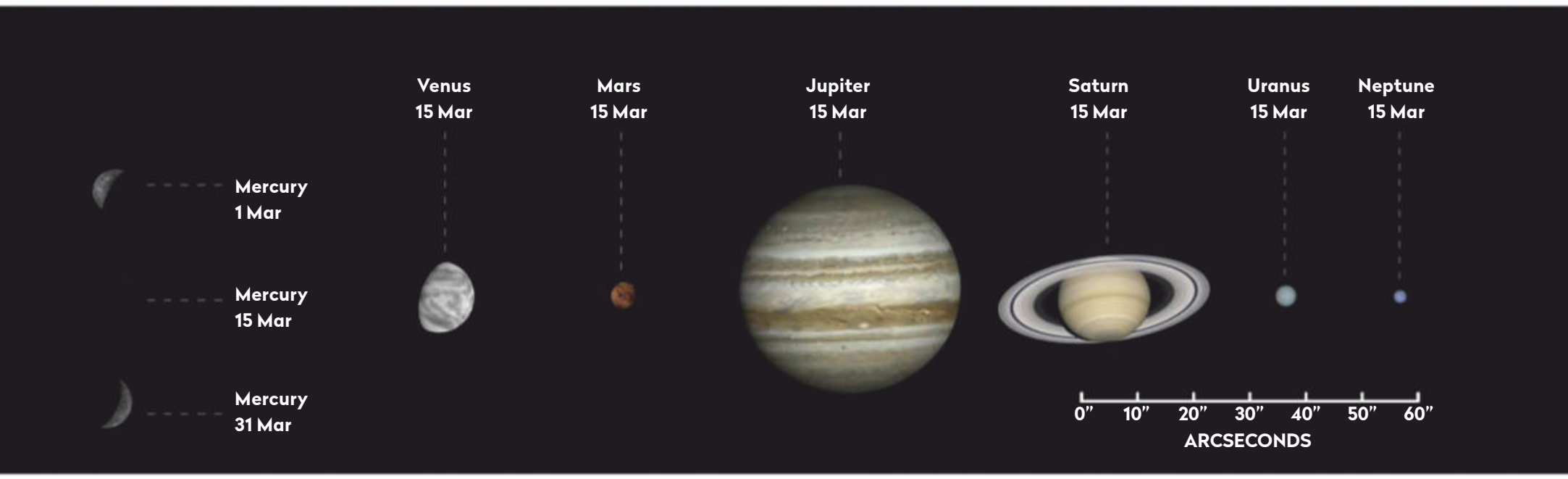
▲ **Mars now appears small through the eyepiece of a telescope, exhibiting a 90% phase**

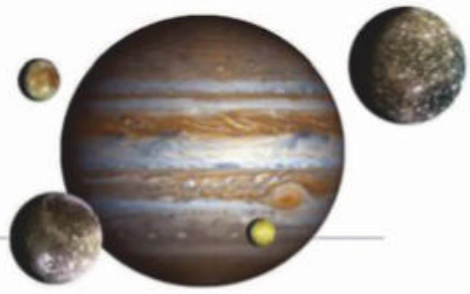
To the naked eye at least, the planet's distinctive salmon pink colour makes it very easy to identify. Frustratingly, although Mars is dimming through the eyepiece, its declination is now quite far north. Unfortunately, it has now drifted too far towards the west to reach its highest position in darkness, and plays a delicate balance of decreasing altitude against expanding twilight.

This month it tracks out of Aries and into Taurus. Two interesting naked-eye meetings occur during the month. On the evening of 11 March, Mars appears 6° north of a 23%-lit waxing crescent Moon. View them at their closest around 20:00 UT. Then at the end of the month, Mars passes to the south of the Pleiades open cluster in Taurus. The best period to see this will be from 28 March through to 3 April, when both objects will appear separated by less than 4°. The closest approach is on the evening of 30 March, when Mars will appear 3° south of the cluster. Take a look as soon as the sky gets dark. This will also be a lovely opportunity to catch Mars and the cluster together in a photograph.

The planets in March

The phase and relative sizes of the planets this month. Each planet is shown with south at the top, to show its orientation through a telescope





Mercury

Best time to see: 1 March, an hour after sunset
Altitude: 7° (low)
Location: Pisces
Direction: West

On 1 March, mag. +0.2 Mercury is well positioned in the evening sky and sets 100 minutes after the Sun. It then starts its move back towards the Sun, encountering a very thin, 1%-lit waxing crescent Moon on 7 March, when it will have dimmed to mag. +1.9. As its orbit nears Earth, things rapidly deteriorate, and it'll be lost from view around 10 March. Inferior conjunction occurs on 15 March, the planet then re-emerging into the morning sky but never reaching a decent altitude before sunrise. It lies 11° east of brilliant Venus on 31 March.

Venus

Best time to see: 1 March, from 06:00 UT
Altitude: 3.5° (very low)
Location: Sagittarius
Direction: Southeast

Beautiful Venus is a morning object shining at mag. -4.0. It forms a Solar System line-up with mag. +1.0 Saturn, a waning crescent Moon and mag. -1.9 Jupiter at the start of March. Look from around 06:00 UT.

A telescope shows it with a 72% gibbous phase, appearing 15 arcseconds across. Over the following days, Venus slowly gets harder to spot. By 31 March it rises less than one hour before the Sun and will appear 81%-lit and 13 arcseconds across.

Jupiter

Best time to see: 31 March, 04:20 UT
Altitude: 13°
Location: Ophiuchus
Direction: South-southeast

Jupiter moves into a favourable morning sky position. Unfortunately for the UK, the planet is in a southern part of the ecliptic so its maximum altitude is only around 15°. If you catch mag. -2.1 Jupiter rising on the morning of 27 March, it'll appear 1.1° south of a 60%-lit waning gibbous Moon's centre.

Saturn

Best time to see: 31 March, 04:30 UT
Altitude: 8° (low)
Location: Sagittarius
Direction: Southeast

Saturn is a morning object south of the Teaspoon asterism in Sagittarius. On 1 March, the mag. +1.0 planet joins the line-up with mag. -4.0 Venus and -1.9 Jupiter. A thin 23%-lit crescent Moon sits 5.8° west of Saturn on this date. On the morning of 2 March, the now 16%-lit waning crescent Moon sits 6.1° east of Saturn.

Telescopically, Saturn is low for UK viewing and it's the planet's northern pole currently tilted towards Earth. The pole tilt changes from 24.1° to 23.6° throughout the month. On the morning of 29 March, centre-to-centre, a 40%-lit waning crescent Moon sits 53 arcminutes south of Saturn.

Uranus

Best time to see: 1 March, 19:00 UT
Altitude: 26.5°
Location: Pisces
Direction: West-southwest

The observing window for Uranus closes this month as the planet loses too much altitude over in the western part of the sky as darkness falls. On 1 March it appears 25° up at this time, but by 31 March it sets before the sky gets truly dark.

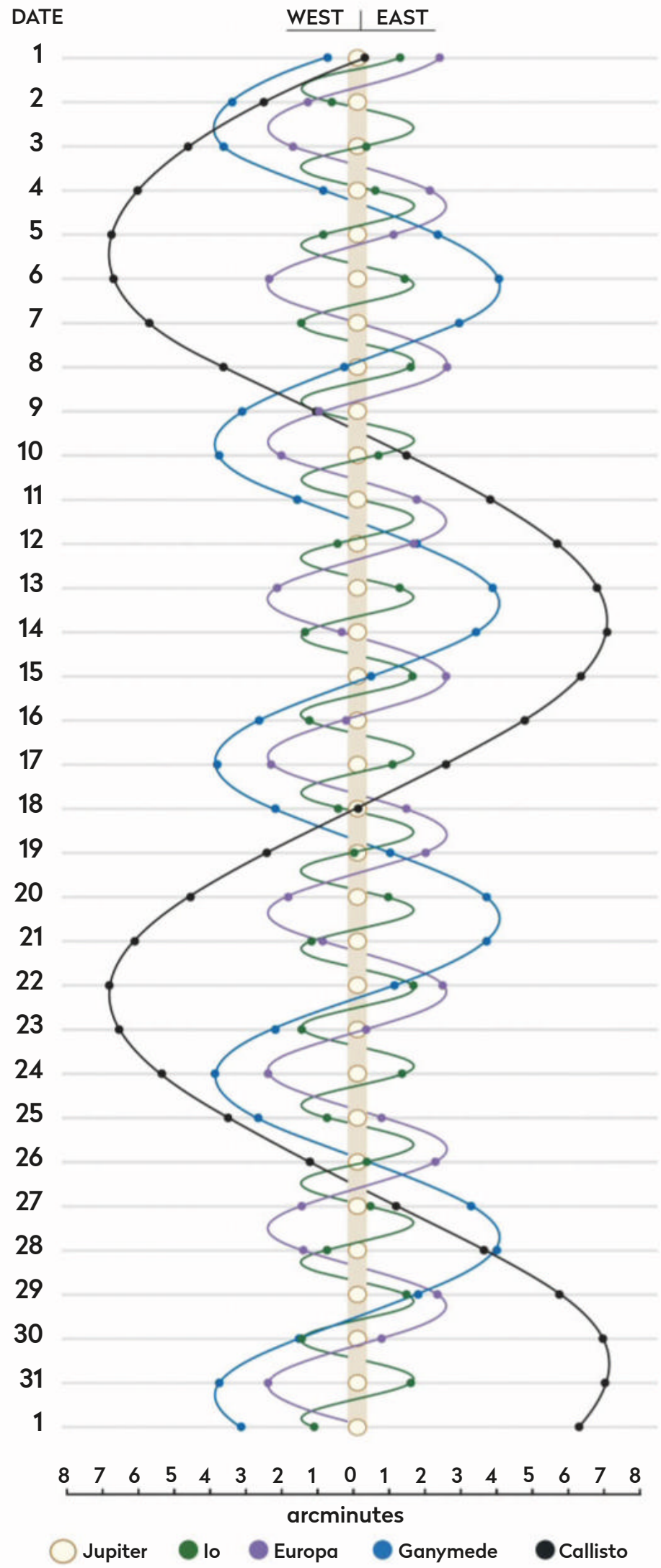
Not visible this month:

Neptune

More **ONLINE**
Print out observing forms for recording planetary events

JUPITER'S MOONS: MARCH

Using a small scope you'll be able to spot Jupiter's biggest moons. Their positions change dramatically during the month, as shown on the diagram. The line by each date represents 00:00 UT.



THE NIGHT SKY – MARCH

Explore the celestial sphere with our Northern Hemisphere all-sky chart

KEY TO STAR CHARTS

- Arcturus — STAR NAME
- PERSEUS — CONSTELLATION NAME
- GALAXY
- OPEN CLUSTER
- GLOBULAR CLUSTER
- PLANETARY NEBULA
- DIFFUSE NEBULOSITY
- DOUBLE STAR
- VARIABLE STAR
- THE MOON, SHOWING PHASE
- COMET TRACK
- ASTEROID TRACK
- STAR-HOPPING PATH
- METEOR RADIANT
- Circlet — ASTERISM
- PLANET
- QUASAR

STAR BRIGHTNESS:

- MAG. 0 & BRIGHTER
- MAG. +1
- MAG. +2
- MAG. +3
- MAG. +4 & FAINTER
- COMPASS AND FIELD OF VIEW (5°)
- MILKY WAY

When to use this chart

1 March at 00:00 UT
15 March at 23:00 UT
31 March at 23:00 BST

On other dates, stars will be in slightly different positions because of Earth's orbital motion. Stars that cross the sky will set in the west four minutes earlier each night.

How to use this chart

1. Hold the chart so the direction you're facing is at the bottom.
2. The lower half of the chart shows the sky ahead of you.
3. The centre of the chart is the point directly over your head.

Sunrise/sunset in March*

Date	Sunrise	Sunset
1 Mar 2019	06:59 UT	17:47 UT
11 Mar 2019	06:35 UT	18:06 UT
21 Mar 2019	06:12 UT	18:25 UT
31 Mar 2019	06:47 BST	19:43 BST

Moonrise in March*

Moonrise times

1 Mar 2019, 04:33 UT	17 Mar 2019, 13:19 UT
5 Mar 2019, 06:51 UT	21 Mar 2019, 19:02 UT
9 Mar 2019, 08:05 UT	25 Mar 2019, –:– UT
13 Mar 2019, 09:37 UT	29 Mar 2019, 03:17 UT

*Times correct for the centre of the UK

Lunar phases in March

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
				1	2	3
4	5	6 NEW MOON	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21 FULL MOON	22	23	24
25	26	27	28	29	30	31

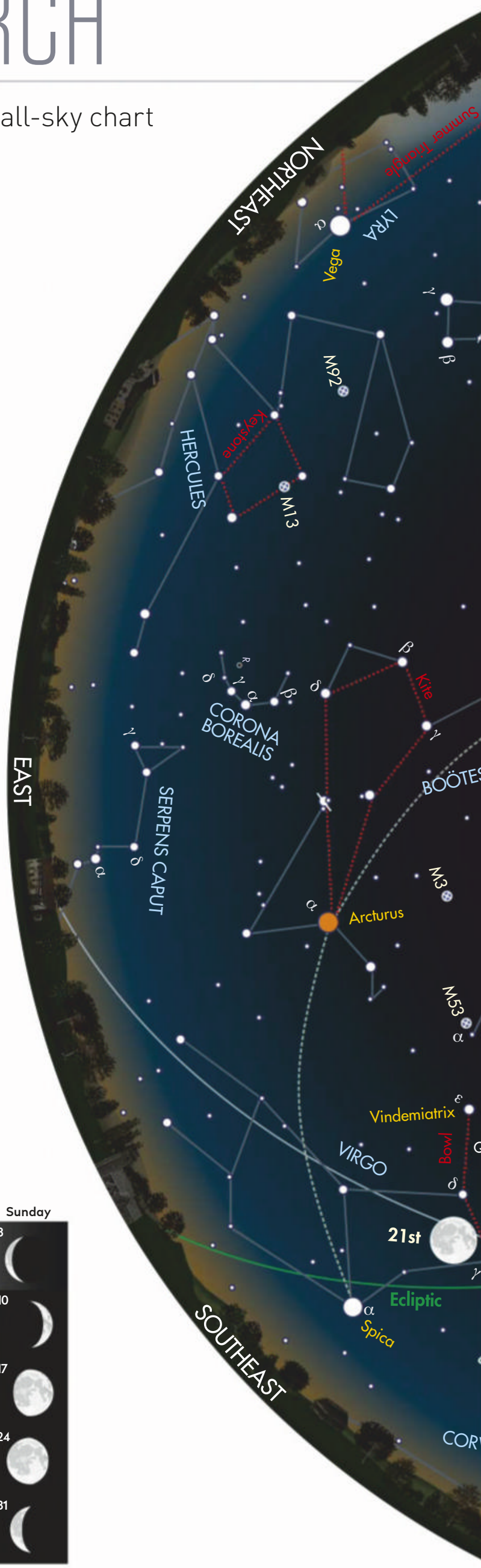


CHART: PETE LAWRENCE

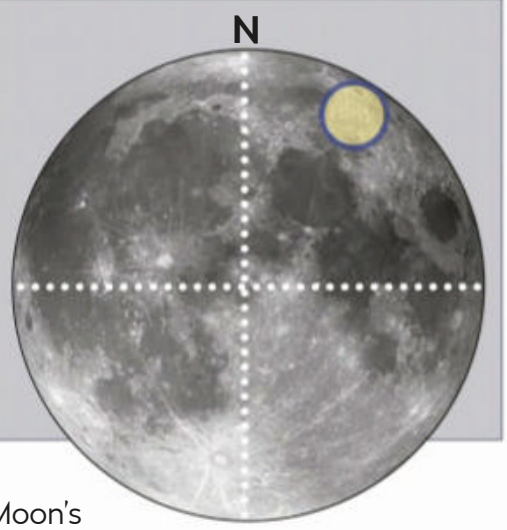
More
ONLINE
Paul and Pete's Virtual Planetarium

MOONWATCH

March's top lunar feature to observe

Atlas

Type: Crater
Diameter: 88km
Longitude/latitude: 44.4° E, 46.7° N
Age: 3.2–3.8 billion years
Best time to see: Four days after new Moon (10 & 11 March) and three days after full Moon (23, 24 & 25 March)
Minimum equipment: 2-inch refractor



Crater Atlas is a distinctive feature of the Moon's northeast quadrant. Located next door to 70km Hercules, it makes a contrast to its neighbour through a telescope because of their marked differences.

Atlas is circular in shape and bounded by an intricately terraced rim wall. The crater is 2km deep and has a complex floor covered in hills and cracks. A lot of its anguished appearance is believed to have come from volcanism. The delicate series of cracks that crisscross its floor are known as **Rimae Atlas**.

"Atlas has pyroclastic patches, the result of 'fire fountains' spouting molten material from below the crater's floor"

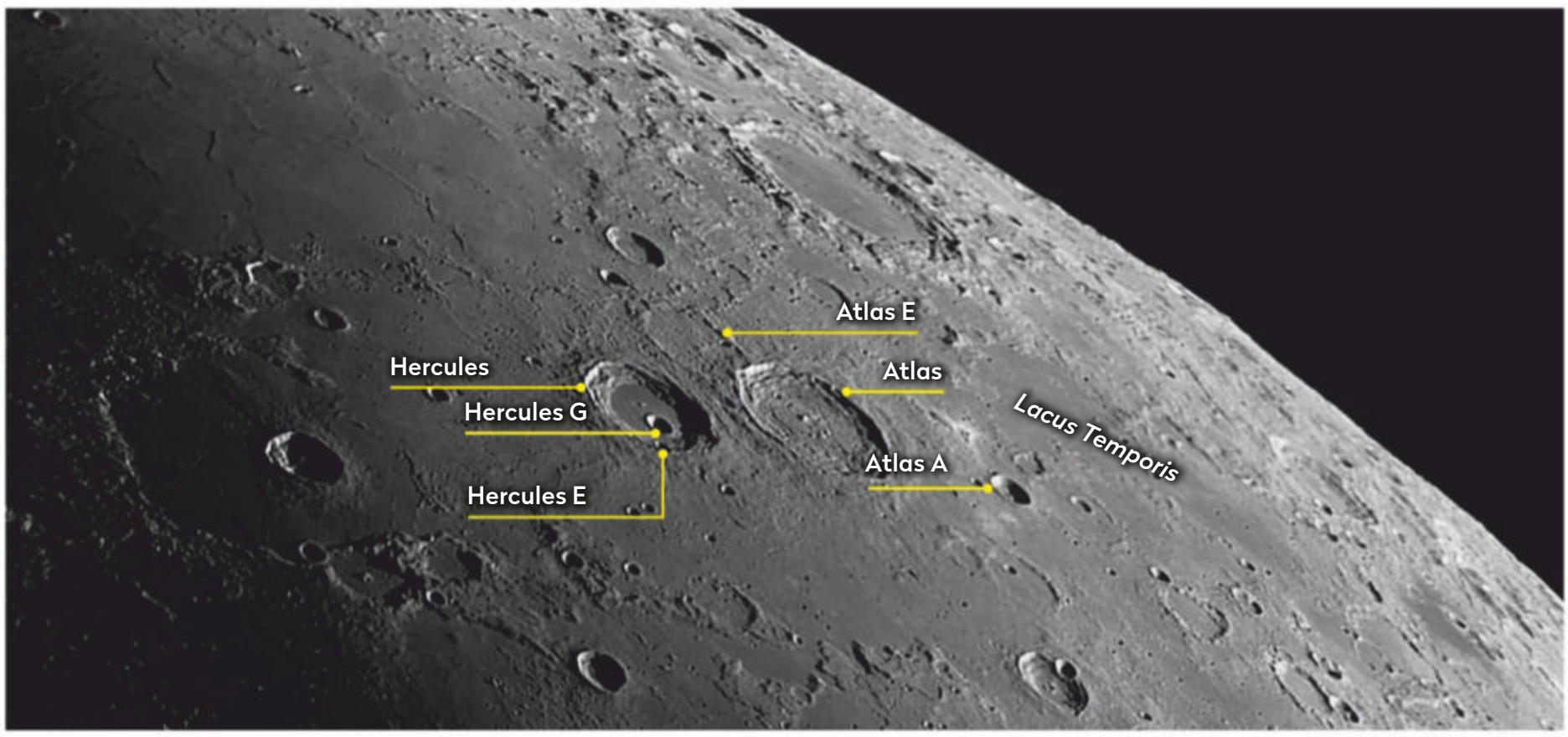
Two dark patches referred to as **Atlas North** and **Atlas South** are very obvious when the crater is lit from overhead. These are pyroclastic patches, the result of 'fire fountains' spouting molten material from below the crater's floor.

The rest of the floor is relatively light in appearance. The rilles that form Rimae Atlas almost appear to spread, like a branching river, north from pyroclastic Atlas South. Further evidence of volcanism can be seen from several dark, haloed craters spread across Atlas's floor – these are craters surrounded by smaller pyroclastic flow. There are few craterlets visible on Atlas's floor through amateur telescopes, the most obvious being a 4.4km example near the northern rim.

After looking at Atlas, it's quite amazing how different nearby **Hercules** appears. Rim to rim, Hercules lies just 30km to the west of Atlas. This is another circular crater which, like Atlas, appears to us as an ellipse as a result of foreshortening. Hercules also has a terraced rim but unlike the cracked floor inside Atlas, the floor of Hercules appears absolutely smooth apart from a few rounded hills. There's a notable intruder to Hercules's floor in the form of 13km **Hercules G**. This sits squarely within the southern half of Hercules but, despite its size, doesn't cause much other disruption. The southwest rim is interrupted by 9km **Hercules E**. Hercules is younger than Atlas at somewhere between 1.1 and 3.2 billion years.

Located north of Atlas and east of Hercules is the 58km ghost crater, **Atlas E**. The rim of this feature is very badly eroded and best seen when the lighting is oblique. It's most prominent to the east and north, but hardly resembles what you'd describe as a classic crater. Atlas appears to overlap the southern rim of Atlas E, so Atlas E is obviously older than Atlas.

A particularly lovely, albeit small feature can be seen 85km to the east of the southern edge of Atlas's rim. Here you'll find a tiny 2.5km ray crater. This is obviously a relatively young impact because its rays are bright and well defined, fanning out in delicate streaks mostly towards the east. A couple of rays can be seen creeping over the boundary edge of **Lacus Temporis**, the Lake of Time. To the south of this unnamed ray crater is bowl-shaped 22km **Atlas A**.



PETE LAWRENCE X 3

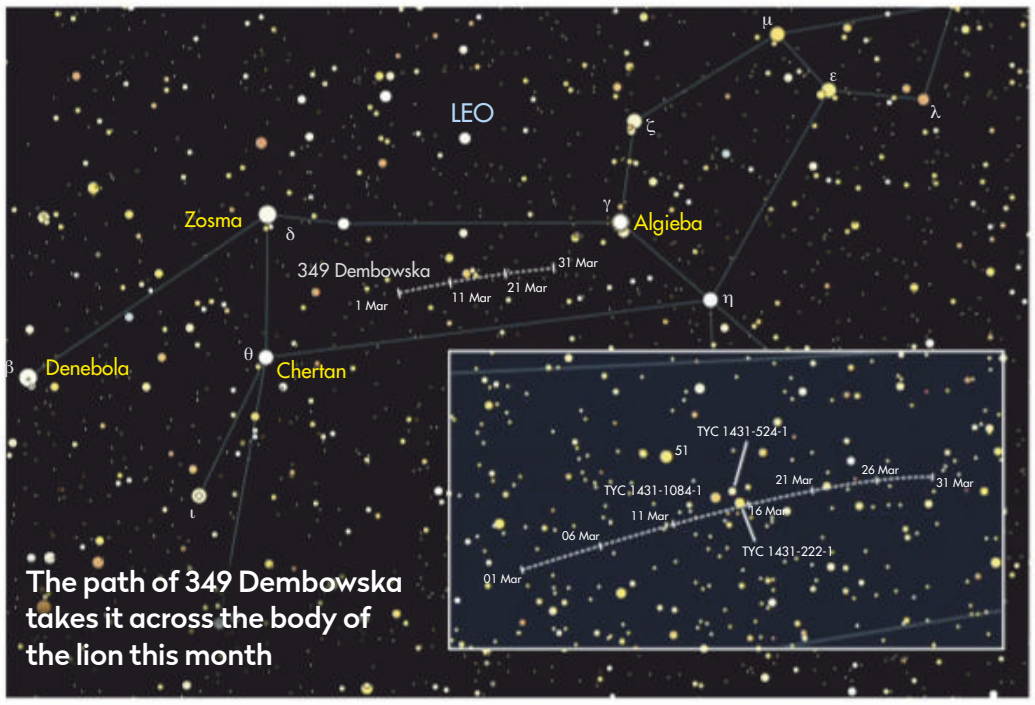
COMETS AND ASTEROIDS

Fast-rotating 349 Dembowska is at the heart of the lion in March

Asteroid 349 Dembowska is a sizeable object that resides in the main asteroid belt between Jupiter and Mars. During March, it is located within the confines of the constellation Leo, the Lion, travelling west through the roughly rectangular shape of the lion's body.

It begins its March track as a mag. +10.3 object one-third of the way along the line joining Chertan (Theta (θ) Leonis) to Algieba (Gamma (γ) Leonis). It ends the month at a dimmer mag. +10.7, three-quarters of the way along the same line. This means it should be visible with a small telescope throughout the whole month. On the nights of 13/14, 14/15 and 15/16 March, it is located close to a small triangle of stars formed by mag. +6.5 TYC 1431-1084-1, mag. +7.1 TYC 1431-222-1 and mag. +7.7 TYC 1431-524-1.

As mentioned, Dembowska is a sizeable object with a diameter around 140km. Discovered in December 1892, it is classified as an R-type asteroid, an uncommon classification which has spectra that show strong evidence of the minerals olivine and pyroxene. Asteroids with this classification tend to be quite bright. Dembowska's albedo – this is the percentage of incoming light that is reflected back – is unusually high at 38.4%. Of the asteroids larger than 75km across, only 4 Vesta has a higher albedo, at 42.3%.



The path of 349 Dembowska takes it across the body of the lion this month

349 Dembowska has a fast rotation lasting 4.7 hours and has probably experienced partial melting in the past. Its surface temperature varies from 40K to around 220K and it takes five years to orbit the Sun, after which time its configuration relative to the Sun and Earth returns to an almost identical position. At aphelion, 349 Dembowska is 3.19 AU from the Sun, a distance which reduces to 2.66 AU at perihelion.

STAR OF THE MONTH

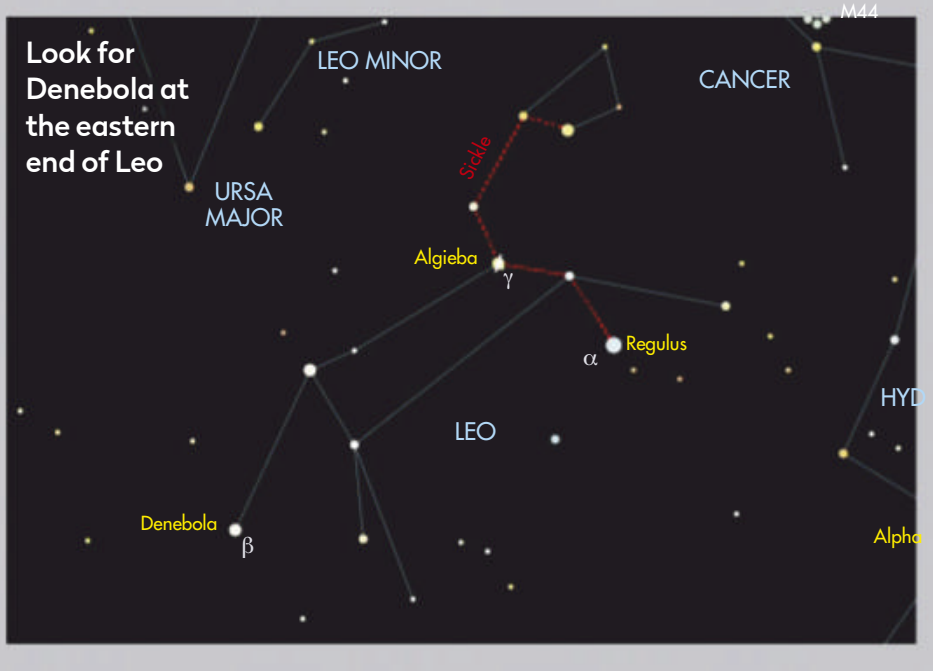
At the tip of Leo's tail, bright Denebola could be forming a new solar system

Marking the end of the constellation Leo the Lion's tail is mag. +2.1 star Denebola (Beta (β) Leonis), its name coming from the Arabic *danab al-asad*, 'tail of the lion'.

Denebola is 36 lightyears away, and is 1.6 times larger and 15 times more luminous than our own Sun. It has the spectral type A3Va, which means it is a slightly more luminous than average main sequence star (the 'Va' part) which appears white in colour (the 'A3' part).

Denebola has 1.73 times more mass than the Sun, but its most interesting and extreme variation is in regards to its spin rate. Where our Sun rotates at a rather leisurely 2km/s, Denebola spins 64x faster at 128km/s. This is fast enough to cause the star to bulge at the equator into an oblate spheroid. In contrast, the slow rotation of the Sun results in one of the most perfect spheres known in nature.

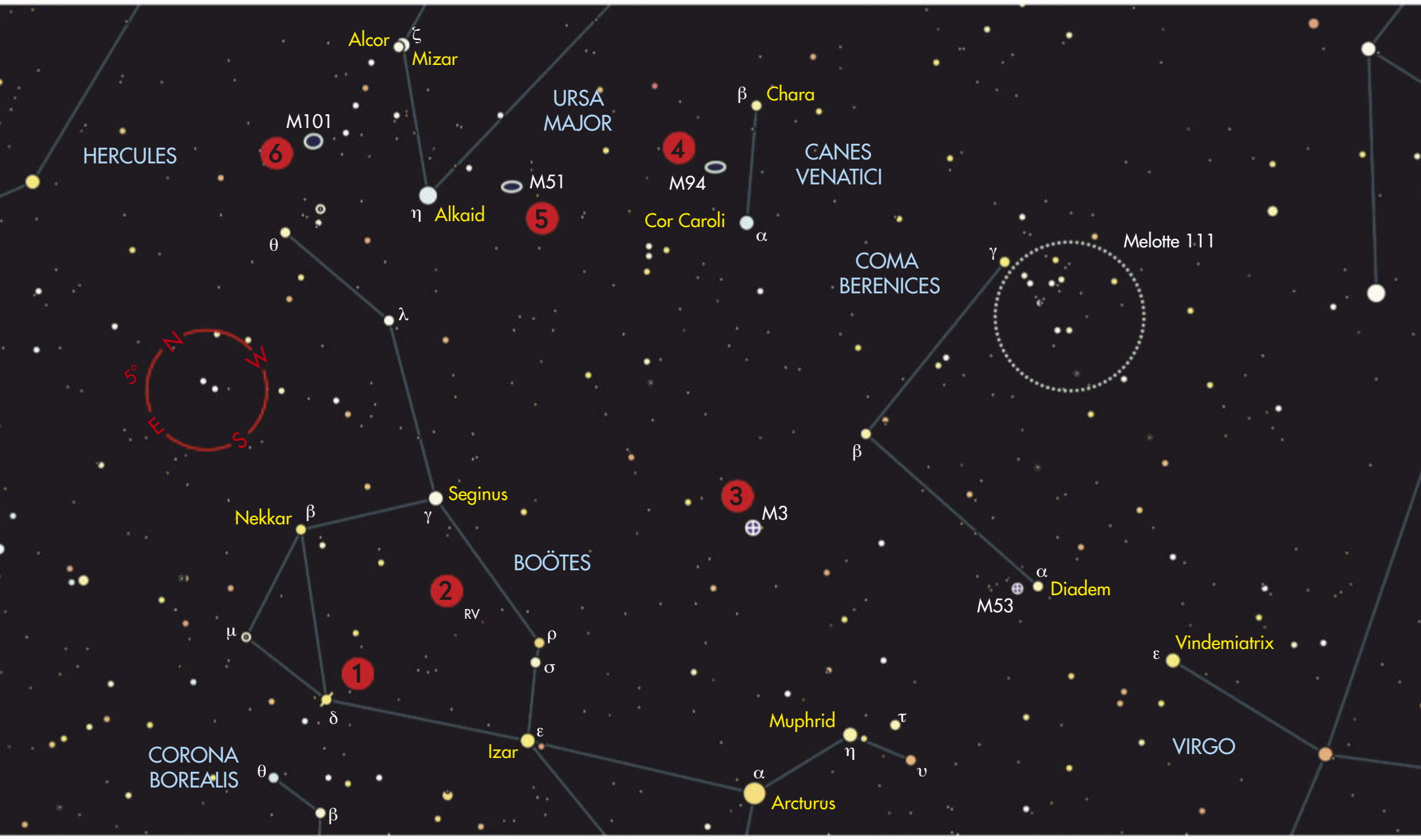
Viewed in infrared, Denebola shows an excess of radiation, hinting at the existence of a disc of debris in orbit around it. This circumstellar disc may be the nursery for a forming solar system, although no planets have yet been identified within it. Detailed analysis of the disc suggests that it extends 5 to 55 AU from the star. The highest concentration of material appears around the 39 AU mark, with a temperature of 120K. Amazingly, structure has been detected within the circumstellar disc. There appears to be a 2 AU hole and a hot 600K dusty ring 4–6 AU in diameter.



BINOCULAR TOUR

With Stephen Tonkin

A binary in Boötes and a star-packed globular are among March's highlights



1 Delta (δ) Boötis

10x 50 We'll get our eye in with Delta (δ) Boötis, an easy double star. The primary is a deep yellow giant, nearly 60 times more luminous than the Sun, which shines at mag. +3.5. Its mag. +7.8 companion, 105 arcseconds to the east, is slightly less yellow. That 105 arcseconds translates to a huge 0.6 lightyears apart at the stars' distance of 117 lightyears and, at that separation, the orbital period is about 120,000 years. ☐ **SEEN IT**

2 RV Boötis

15x 70 You'll find this red variable star a little more than 2.5° northeast of Rho (ρ) Boötis, in between two mag. +6.3 stars, which are the brightest stars in the field of view of 15x70 binoculars. RV Boötis is a semi-regular variable with a period of 288 days. Its magnitude supposedly varies from +7.2 to +9.8, but recently it has only been falling to mag +8.7, so it remains well within binocular capability. ☐ **SEEN IT**

3 M3

10x 50 Our next target is one of the best globular clusters in the northern sky. To find it, you need to imagine two lines: it lies very near the point where a line from Cor Caroli (Alpha (α) Canum Venaticorum) to Arcturus (Alpha (α) Boötis) intersects the line from Seginus (Gamma (γ) Boötis) to Diadem (Alpha (α) Comae Berenices). What looks like a severely defocused star is the glow of more than 150,000 stars lying 34,000 lightyears away. ☐ **SEEN IT**

4 M94

15x 70 Our final three targets are galaxies. To find the first, take the mid-point of a line between Cor Caroli and Chara (Beta (β) Canum Venaticorum), then navigate 2° in the direction of Alkaid (Eta (η) Ursae Majoris). Here, possibly needing averted vision at first, you should find the faint glow of light that has taken 23 million years to reach us from the mag. +8.9 spiral galaxy, M94. ☐ **SEEN IT**

5 M51

10x 50 M51, the Whirlpool Galaxy, is brighter and very easy to find. Imagine that a line from Mizar (Zeta (ζ) Ursae Majoris) to Alkaid is the upright of a letter 'L'. M51 lies at the 'toe' of this L, 3.5° from Alkaid. Expect to see a tiny fuzzy patch, slightly smaller than M94, that is the glowing equivalent of 25 billion Suns that lie 20 million lightyears away. If you use averted vision, can you tell that it's slightly elongated? ☐ **SEEN IT**

6 M101

10x 50 Although it's the closest of our three galaxies, M101's surface brightness is low so use low magnification in pristine sky conditions. Picture an equilateral triangle with Mizar and Alkaid as its base; M101 is just inside the third apex. With averted vision, you should notice a small ghostly patch that's very slightly brighter than the rest of the sky. ☐ **SEEN IT**

☑ Tick the box when you've seen each one

PETE LAWRENCE X 3

THE SKY GUIDE CHALLENGE

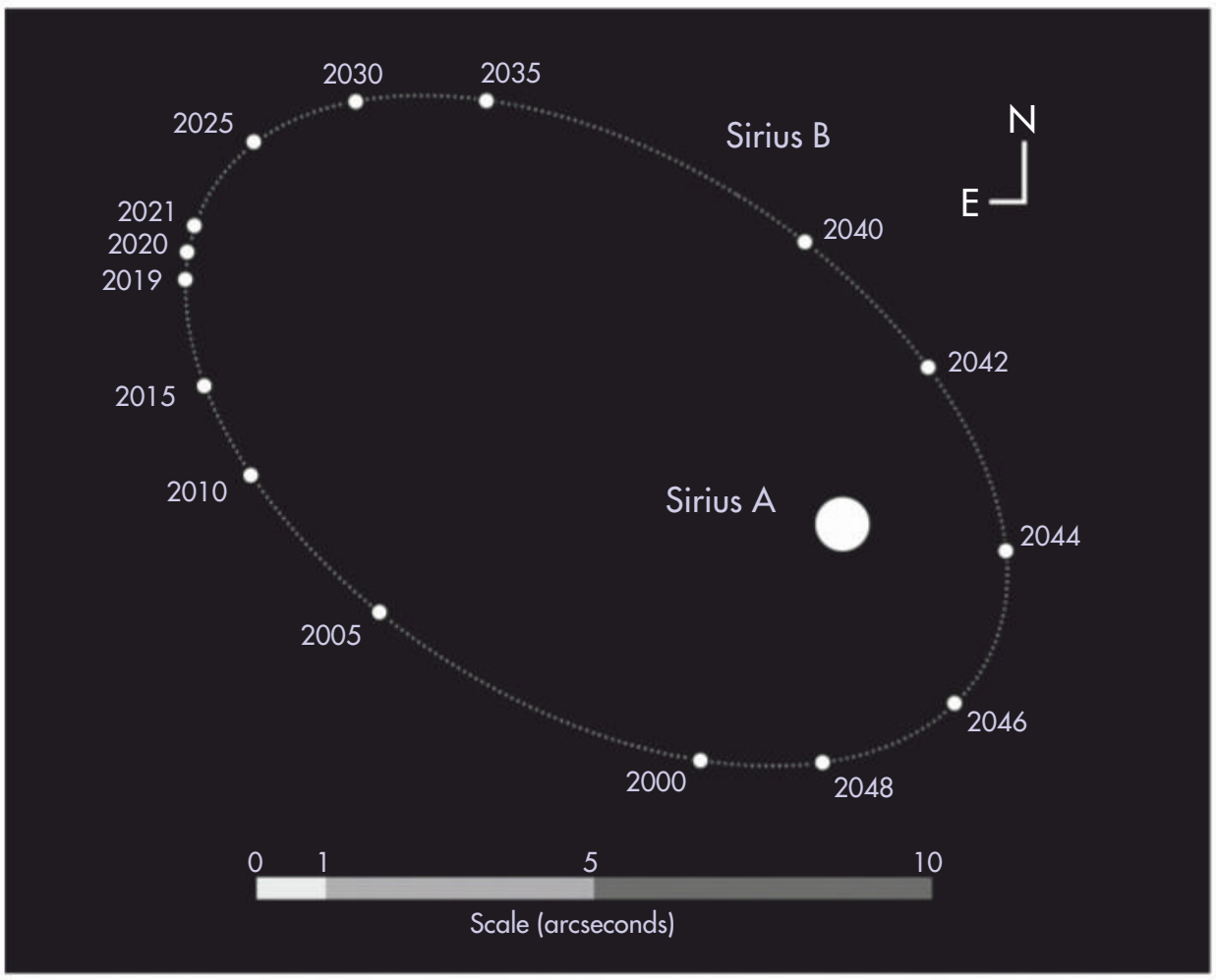
Beware of imitations when hunting the Pup Star, Sirius's elusive companion

The brightest star in the night sky has a companion, and trying to image or observe it is one of the great challenges for amateur astronomers.

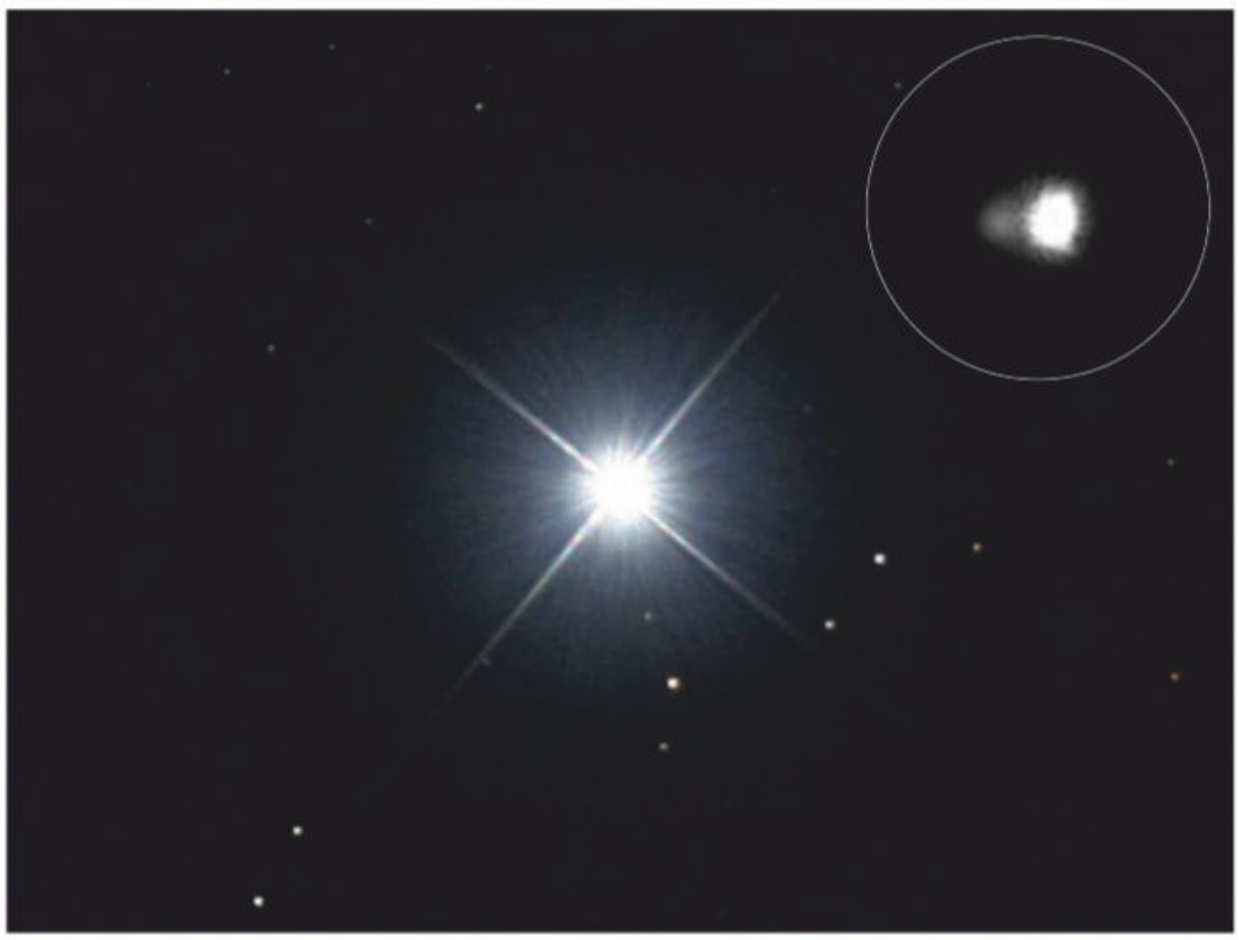
The primary is Sirius A, a white main sequence star that appears to shine at mag. -1.5. The alpha star of Canis Major the Great Dog, it's also known as the Dog Star, which is why its hard-to-find companion, the white dwarf Sirius B, has been dubbed the 'Pup Star'.

On paper, Sirius B should be relatively easy to see as it shines at mag. +8.5. In practice, especially from the UK, it's anything but easy. This is down to the brightness and proximity of Sirius A, together with the restricted altitude that the star achieves above UK horizons. From the UK, Sirius only manages to reach an altitude of 20° when due south. This means it tends to be affected by poor seeing. You can see evidence of this on any clear dark night. Sirius appears to flicker and flash different colours. The flickering is due to seeing, while the colour flashes arise from a combination of seeing and atmospheric dispersion, which smear the star's light into its component spectrum colours.

The good news is that Sirius B has been slowly separating from its primary over recent years. In 2019 it lies 11 arcseconds from Sirius A. This means that now is an excellent time to attempt to either observe or image it.



▲ **Sirius B is slowly moving away from Sirius A, which should make detection a little easier**



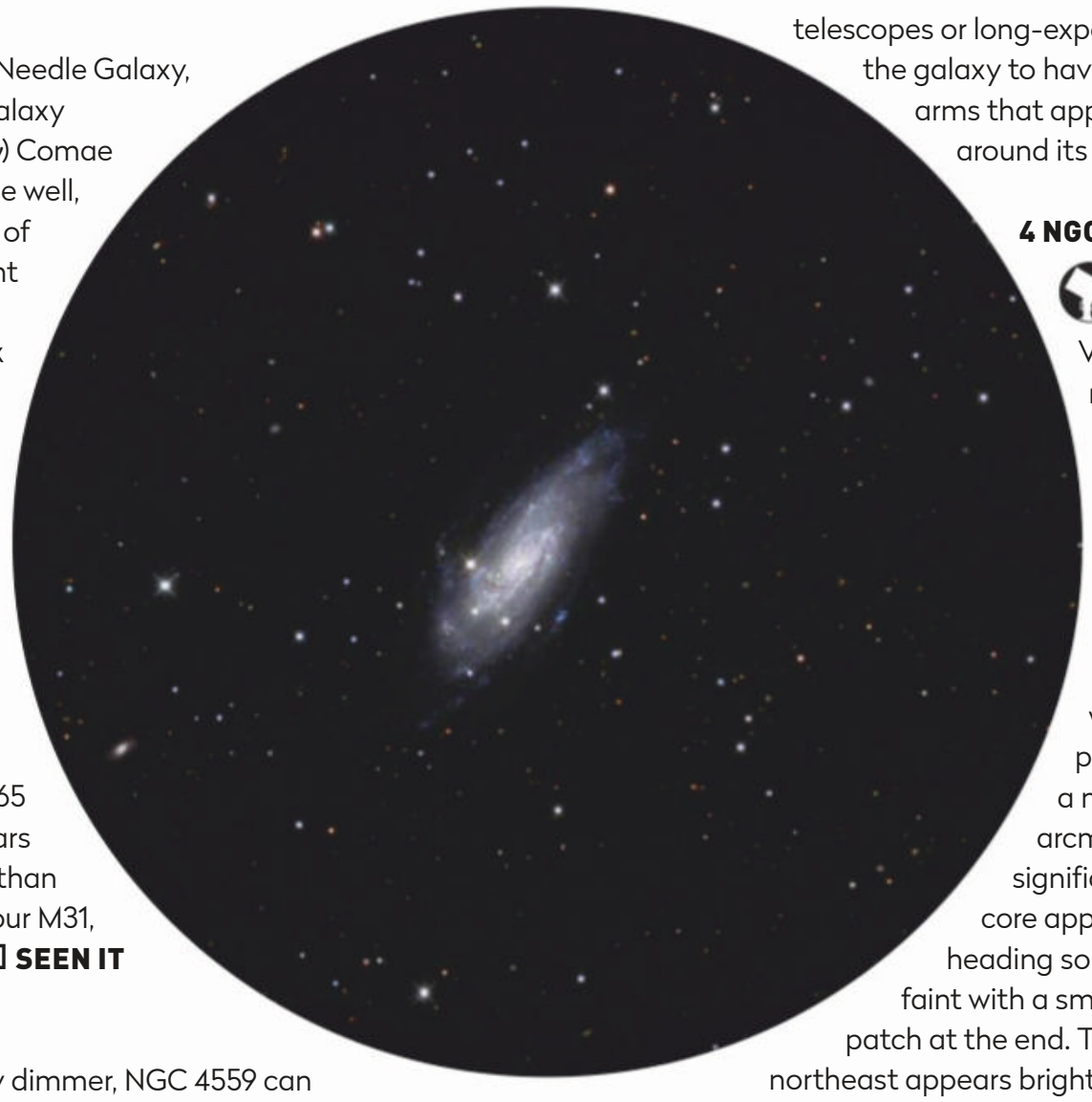
▲ **There are lots of faint field stars near brilliant Sirius, but the true 'Pup' – shown in the infrared capture (upper right) as the faint object on the left – is much closer in**

There have been many claims to have imaged Sirius B in the past few years. Quite a few of these have been false captures which haven't taken into account the separation distance: it is on the scale of apparent planetary disc size. Jupiter's apparent size is currently over three times the separation distance! Many of the images actually record another faint field star that appears close to Sirius but much further out than Sirius B. One way to remove any doubt is to image an object of comparable size to 11 arcseconds to calibrate your imaging setup. This could be a planet, a lunar feature or a more evenly matched double star. For example, the star Nair al Saif (Iota (ι) Orionis) at the bottom of Orion's Sword consists of a mag. +2.8/+7.7 pair separated by 11 arcseconds.

Various methods have been put forward to assist with the sighting of Sirius B. One is to place Sirius off the southwest edge of your field of view so its brilliance is hidden. Another is to observe or image Sirius when the sky is still bright at twilight. The brighter background reduces contrast and should, in theory, make Sirius B that much easier to spot. However you try it, good luck and let us know how you get on.

DEEP-SKY TOUR

A selection of striking galaxies on the border of Canes Venatici and Coma Berenices



▲ **Spiral galaxy NGC 4559 in Coma Berenices, where a mag. +13.2 type-II supernova explosion was observed in 1941**

GÜNTER KERSCHHUBER/CCDGUIDE.COM, CHART BY PETE LAWRENCE

1 NGC 4565

NGC 4565, the Needle Galaxy, is a mag. +9.5 galaxy 3° southwest of Gamma (γ) Comae Berenices. It earns its name well, appearing like a thin sliver of light. In a 6-inch instrument its appearance is grainy with the hint of a thin dark dust lane along part of its length. The central bulge is easy to observe in a 10-inch scope and it's interesting to see how far you can trace the dust lane either side of it. A mag. +13.5 star appears centrally positioned, 1.5 arcminutes northeast of the galaxy's core. NGC 4565 is about 43 million lightyears away and more luminous than our famous closer neighbour M31, the Andromeda Galaxy. ☐ **SEEN IT**

2 NGC 4559

Only marginally dimmer, NGC 4559 can be located 1.9° further north. At mag. +9.9, it's still a viable subject for smaller scopes, a 6-inch scope revealing its definite oval shape, 9x2 arcminutes in size. The oval looks fairly even in brightness, with only a subtle hint of brightening towards its core. A reddish mag. +11.9 foreground star appears close to the galaxy's northeast edge. NGC 4559 is probably around 29 million lightyears away. Original distance estimates came from the type-II supernova observed within NGC 4559 back in 1941. The supernova reached mag. +13.2 at its peak. ☐ **SEEN IT**

3 NGC 4274

Brightness dips slightly to mag. +10.3 as we locate our next target, the barred spiral galaxy NGC 4274. This lies at a distance of 45 million lightyears and presents as a low surface brightness oval of light through smaller instruments. Through a 6-inch telescope the oval appears 3.5x1 arcminute in size. A subtle brightening can be seen towards the galaxy's centre. A 300mm scope shows NGC 4274 to be around 6x1.5 arcminutes, with a now well-defined core region and a star-like nucleus. Very large telescopes or long-exposure imaging show the galaxy to have overlapping outer arms that appear to form a ring around its core. ☐ **SEEN IT**

4 NGC 4656

Our next target takes us north into Canes Venatici where our best navigational guide is the pair of stars TYC-2528-2277-1 and TYC-2528-2057-1, 5.2° north and slightly east of Gamma (γ) Comae Berenices. Edge-on spiral galaxy NGC 4656 lies 2.4° west-southwest of this pair. A 12-inch scope shows a needle-like object 9x1.2 arcminutes in size with significant asymmetry. The core appears mottled, the section heading southwest from it being faint with a small marginally brighter patch at the end. The portion heading northeast appears brighter with a 'hook' at the end designated as NGC 4657. The overall appearance has given rise to it being called the Hockey Stick or Crowbar Galaxy. ☐ **SEEN IT**

5 NGC 4631

Approximately 0.5° further northwest, mag. +9.2 NGC 4631 appears as a 10x1.5 arcminute granular bar of light in a 6-inch instrument. A mag. +12.3 star appears on the northern edge of the brightest part of the bar. Larger instruments show NGC 4631's distinctive shape, narrowing to a thin point to the west, with the eastern end looking blunt and fading out fast, leading to its name: the Whale Galaxy. A lot of mottling is visible with larger instruments and a challenge is to see the dim galaxy NGC 4627 as a weak extension slightly northwest of the 12th magnitude star on the whale's back. ☐ **SEEN IT**

6 NGC 4244

NGC 4244 can be found 2.1° southwest of mag. +5.0 6 Canum Venaticorum. This mag. +10.1 galaxy appears like a 10x1 arcminute thin streak of light in a 6-inch scope. The light streak is uneven in brightness, with dimmer patches immediately either side of the core. The core appears subtly brighter and with a tangible size. Larger instruments reveal the core bulge but it's by no means as evident as it was in our first target, NGC 4565. A 12-inch instrument will show a definite asymmetry to the galaxy's shape, the northeast portion appearing brighter. ☐ **SEEN IT**

This Deep-Sky Tour has been automated ASCOM-enabled Go-To mounts can now take you to this month's targets at the touch of a button, with our Deep-Sky Tour file for the EQTOUR app. Find it online.

More **ONLINE**

Print out this chart and take an automated Go-To tour. See page 5 for instructions.

CANES VENATICI

COMA BERENICES

α

Cor Caroli

10

6

13h00m

12h30m

+40°

+35°

+30°

+25°

N

E

W

S

2°

1°

NGC 4244

NGC 4214

NGC 4399

TYC-2528-2277-1

TYC-2528-2057-1

NGC 4203

NGC 4631

NGC 4656

NGC 4414

NGC 4314

NGC 4274

NGC 4245

NGC 4278

NGC 4448

γ

NGC 4251

NGC 4559

31

30

14

16

13

12

17

Melotte 111

NGC 4565

NGC 4494

1

2

3

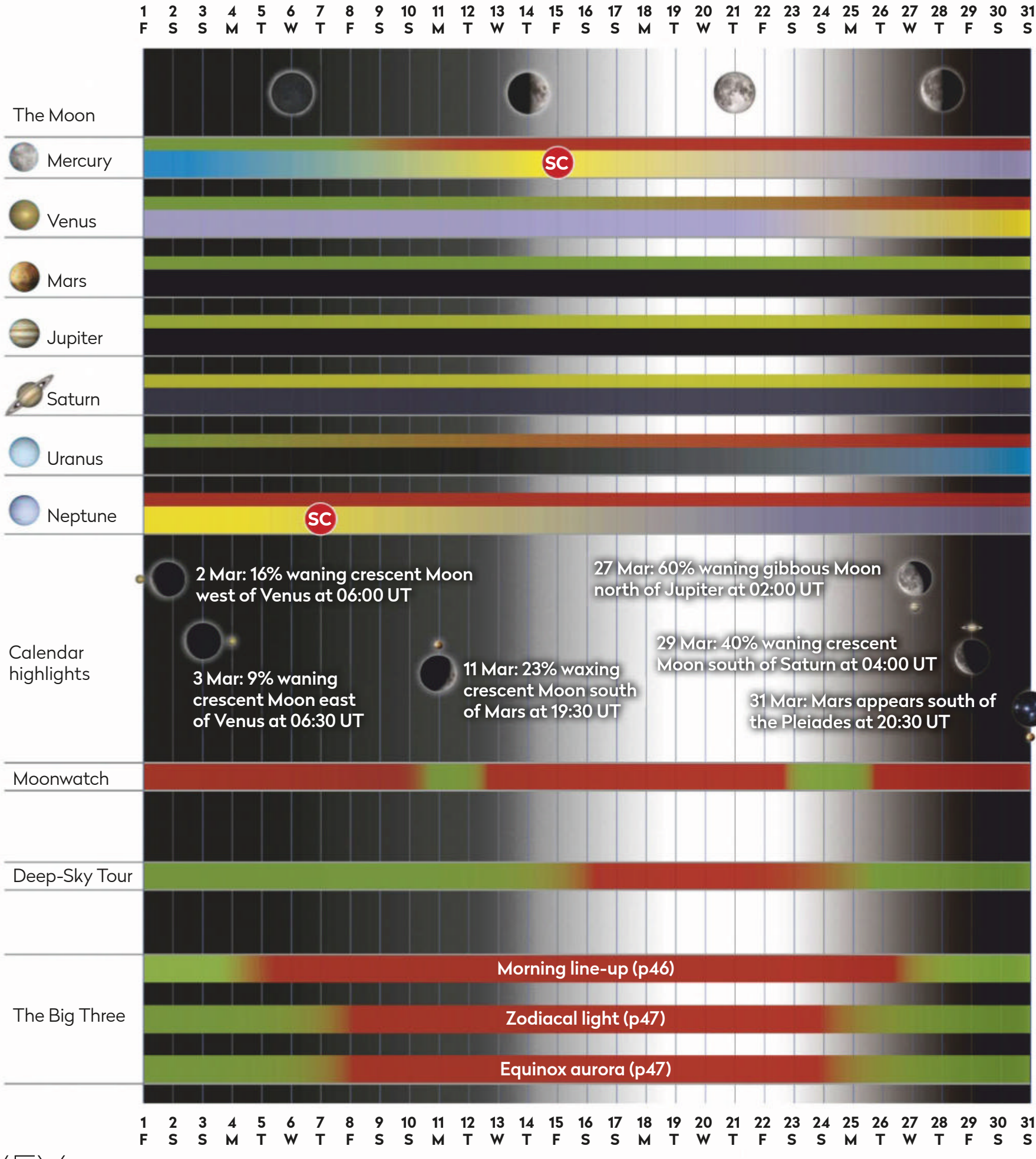
4

5

6

AT A GLANCE

How the Sky Guide events will appear in March



KEY

Observability

Optimal | Poor

Best viewed

Morning twilight | Daytime | Evening twilight | Night

Sky brightness during lunar phases

Dark (first quarter) | Light (full Moon) | Dark (last quarter) | Total darkness (new Moon)

- IC — Inferior conjunction (Mercury & Venus only)
- SC — Superior conjunction
- OP — Planet at opposition
- Meteor radiant peak
- Planets in conjunction
- Full Moon
- First quarter
- Last quarter
- New Moon

CHART BY PETE LAWRENCE

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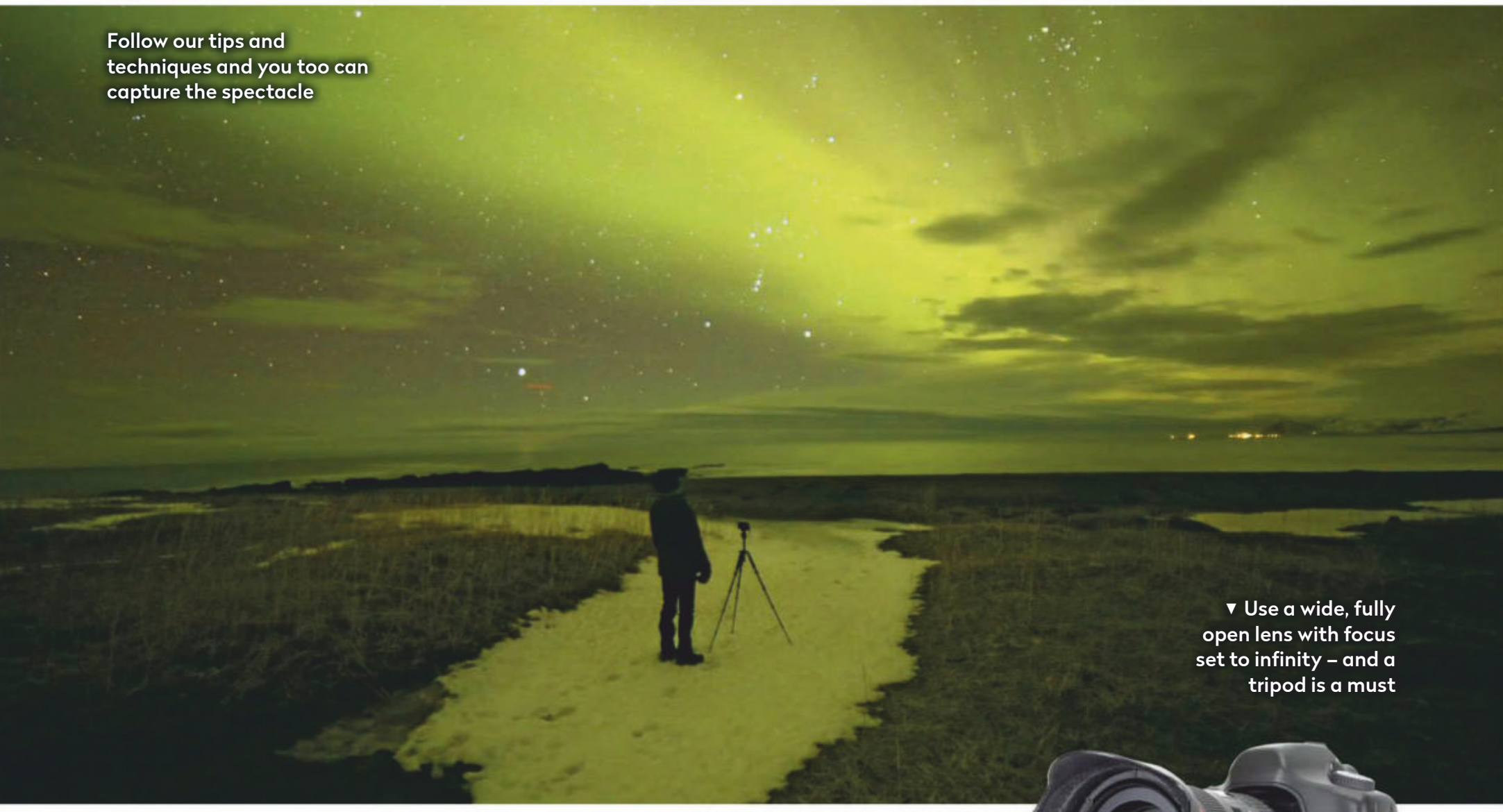
The fundamentals of astronomy for beginners

EXPLAINER

Taking impressive aurora photographs

Even beginners can successfully capture the Northern Lights with these simple tips



Follow our tips and techniques and you too can capture the spectacle

▼ Use a wide, fully open lens with focus set to infinity – and a tripod is a must

Taking impressive aurora photos isn't difficult. If you have a manual camera and you know how to use it, you too can take incredible aurora images. The basics are: always use a tripod, shoot in RAW, remove any filters and have a release cable or timer to trigger the shutter. After that, it's mostly about finding the right spot and waiting. When the perfect moment finally arrives, here's our guide to making the most of the opportunity.

1. Switch off the lights

Can you operate your camera blind? Photographing the Northern Lights means making adjustments to exposure and ISO in the dark. Prepare by sitting in a darkened room at home to practise changing settings until your thumb knows which dials to adjust and what buttons activate which menus. Think you're ready? Now try it with your eyes closed. It may seem silly, but knowing your camera intimately means you won't risk missing a great shot while fumbling with the settings.

2. Choose a wide angle lens

The aurora can appear right across the night sky, so the wider angle lens you use, the more impressive your vista will look. An 18–55mm kit lens is fine, but know that cheaper crop-sensor (APS-C) DSLR cameras and more expensive full-frame models get different results. For example, a 24mm lens on a full-frame DSLR produces a wide angle as promised, but the same specification of lens on an APS-C DSLR produces a narrower image

JAME CARTER X 3, ISTOCK

▲ **The best photos often set the aurora behind features such as trees, people and mountains**

equivalent to what you would expect from a 38mm lens on a full-frame DSLR. Whatever you use, set the aperture as wide open as possible, probably f2.8 or so.

3. Keep it sharp

Practice manually focusing on infinity. Take test shots outside at night and check for sharpness to determine exactly where the infinity focus point is on your lens – it may not be where the manufacturer indicates. Nothing's worse than taking a spectacular aurora image, only to find that it's ruined by blurry stars.

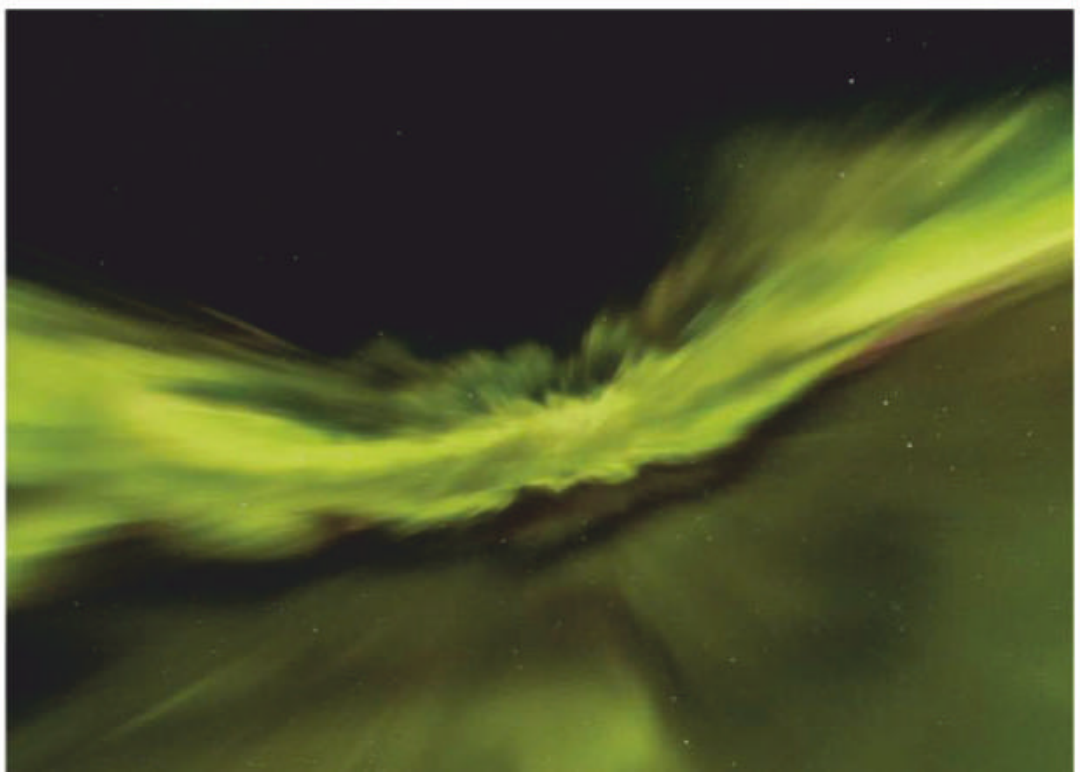
4. Get to the Arctic Circle

For your best chance of catching a display, head to the Arctic Circle between 64° and 70° North, the closest places to the UK being Iceland and Lapland (the northern parts of Norway, Sweden and Finland). Northern Russia and Alaska see the aurora too. Aurora activity is constant throughout the year, though the longer, darker nights between September and March emphasise the aurora's vivid colours.

5. Think about composition

Photos featuring only 'green clouds' are dull. Reflections, rugged foregrounds and even people often feature in the best images. Scout out locations in daylight looking for interesting trees, buildings or mountains. But be flexible; the northern lights probably won't appear where you want them. A good rule of thumb is to think of the aurora as a backdrop to an already well-composed landscape photograph.

▼ **You'll need to shoot fast with a short exposure if the corona passes directly above you**



6. Capture a 'forest fire'

Photographing the Northern Lights successfully is largely about hunting down clear skies. Once clear, the most common sighting is of an almost stationary green glow arcing above the northern horizon. To the human eye it looks greyish and often not much of a spectacle at all. However, take a long exposure (try 25–30 seconds on ISO 800–1600) in a beautiful snowy landscape and the resulting image can be delightful.

7. Keep your boots by your bed

The Northern Lights can appear at any time of night, so keep your boots by your bed. Set an alarm and check the sky every hour or so, or if your hotel has an aurora wake-up service, use it. Keep an eye on the aurora forecast at www.aurora-service.eu too. If it's clear at night, sleeping at all may be a mistake.

8. Arcs, bands and curtains

Faster-moving arcs of aurora often turn into more curved bands that gently sway across the sky. These can coalesce as curtains, with ripple features and occasional red colours. For these kinds of phenomena, try increasing the ISO to 1600 or 3200, and reducing the exposure to 5 or 10 seconds.

9. Capture a corona

If you're lucky enough to find yourself right in the path of an auroral display, act fast. With the corona directly above and moving very quickly, you'll have no choice other than to point upwards and shoot. Resist the temptation to bump up the ISO too much – you'll blow-out the bright heart – and instead go for one-second exposures.

10. Prevent lens fog

Cameras hate going from cold to warm and back again. Once your camera is outside, try to leave it there. If you bring it back inside it will fog up immediately, potentially spoiling a future shot. If that is not possible, put it in a camera bag and zip it up before you bring it back inside. A more drastic technique is to go to Iceland. Thanks to the jet-stream, it rarely gets much below freezing there.

Jamie Carter is a well-travelled amateur astronomer and author of *A Stargazing Program for Beginners: A Pocket Field Guide*

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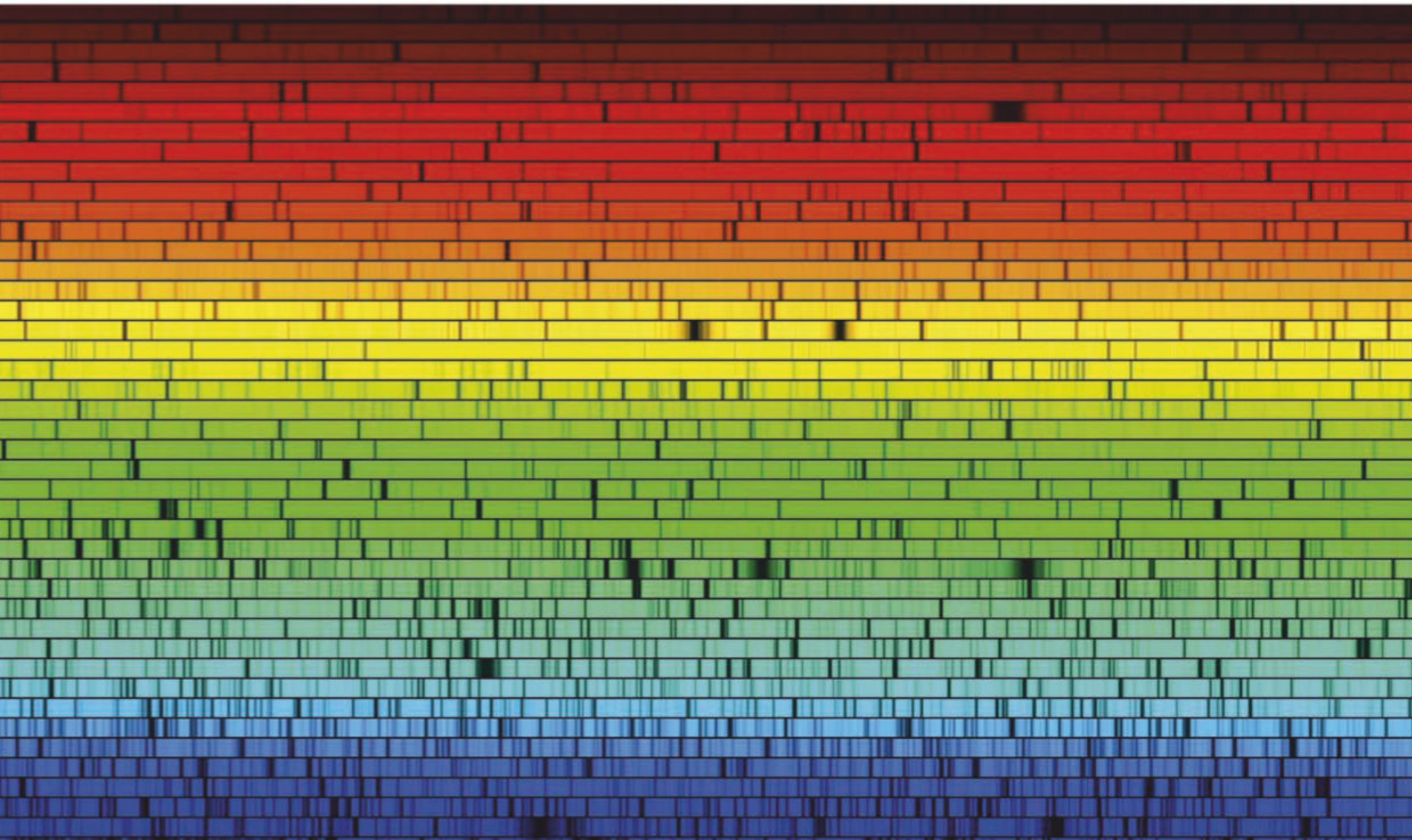
Imaging for SCIENCE

Supernova SN 2013ej discovered in spiral galaxy M74 in 2013, with comparison star magnitudes marked

PART 10: DEEP SKY continued

In the final installment of our guide to boosting the scientific value of your astrophotos, **Pete Lawrence** tells us how using spectroscopy and photometry can uncover the secrets hidden in starlight

PETE LAWRENCE



▲ **A high-resolution spectrum of the star Arcturus using data from the Kitt Peak National Observatory. It shows many dark 'absorption' lines that indicate the presence of specific elements – the star's unique 'light fingerprint' that spectroscopy reveals**

The last part of our Imaging for Science series continues our look at the scientific observations that can be undertaken by amateurs on deep-sky targets.

This month we are going to look at two very significant processes – photometry and spectroscopy – that, with care, can contribute significantly to the scientific study of the cosmos. Photometry in particular is an important tool used in many areas of astronomy. We have already encountered it (in Part 4, January 2018) for measuring the brightness of comets and asteroids. Here we see how it can be employed to determine the brightness of stars and (on page 67) of one of the most violent processes in the Universe, supernovae.

These topics have significant depth to them and here we offer a general overview of their capabilities and practices to get you started. Deep-sky imaging is a term that essentially covers everything we can see outside of our own Solar System. As well as the usual suspects such as galaxies, nebulae and clusters, it also includes the study of individual and multiple stars. Much of the work here involves converting the light from these objects to produce numbers that can be subsequently analysed as data. Variable stars are a classic example; by accurately measuring their magnitude it's possible to generate a light curve of their activity and deduce a lot about their nature. Very precise measurements of a star's light may also contribute to exoplanetary science by recording the tiny dip in light that occurs when a planet transits its sun. Measuring the intensity of light across a star's spectrum provides another exciting area of research where amateurs can make real contributions to the scientific data pool.

High-speed photometry is another important area for research and recently came to the fore with observations of V404 Cygni in June 2015. The rapid brightness flickering that was recorded by amateurs with 200mm or larger telescopes represented the visible light output from the accretion disc around a black hole. This was the first time such flickering had been detected in the visible part of the spectrum.

The Sky at Night presenter **Pete Lawrence** is an astrophotographer with a particular interest in digital imaging

Hardware & software

HARDWARE
- **Telescope**
- **Equatorial mount**
- **Autoguider**
- **Camera (DSLR, cooled astronomical CCD, high frame rate)**
- **Laptop**

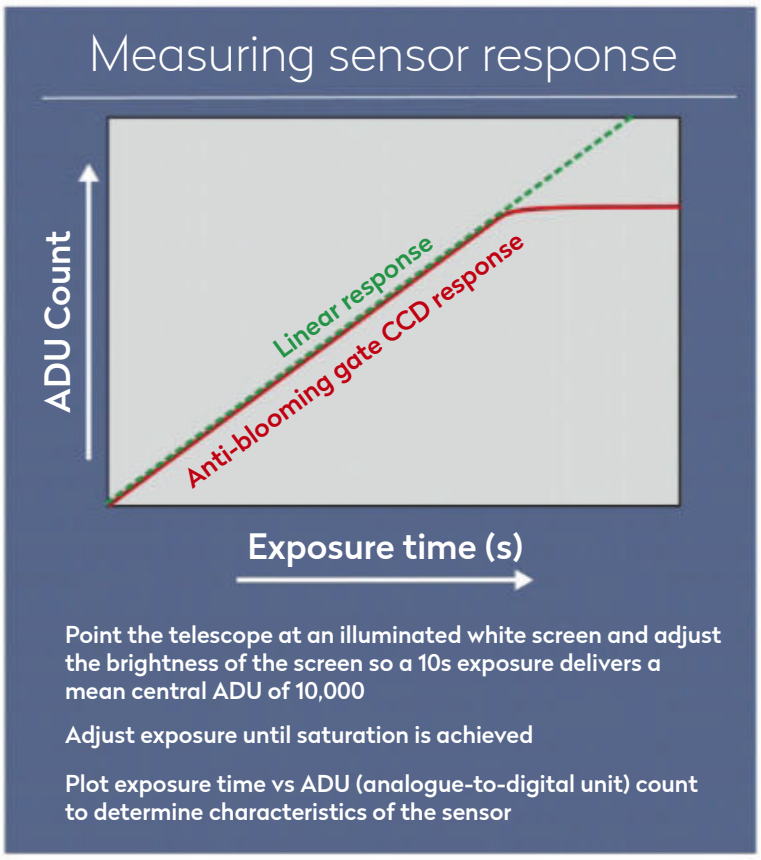
SOFTWARE
- **Maxim DL**
- **AIP4WIN**
- **AstroimageJ**
- **RSpec**
- **PixInsight**
- **APT**
- **Sequence Generator Pro**

N.A.SHARP/NOAO/AURA/NSF, PETE LAWRENCE X 3

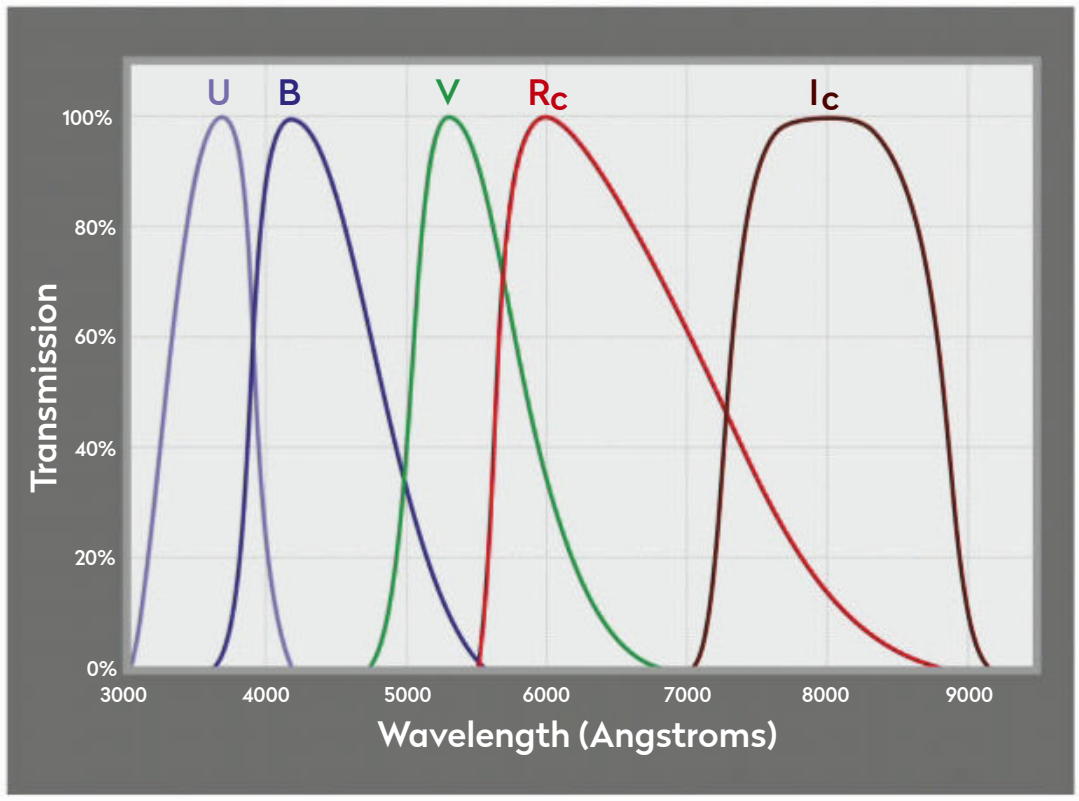
PROJECT 1

Making a start in PHOTOMETRY

Use your CCD to measure the brightness of deep-sky objects

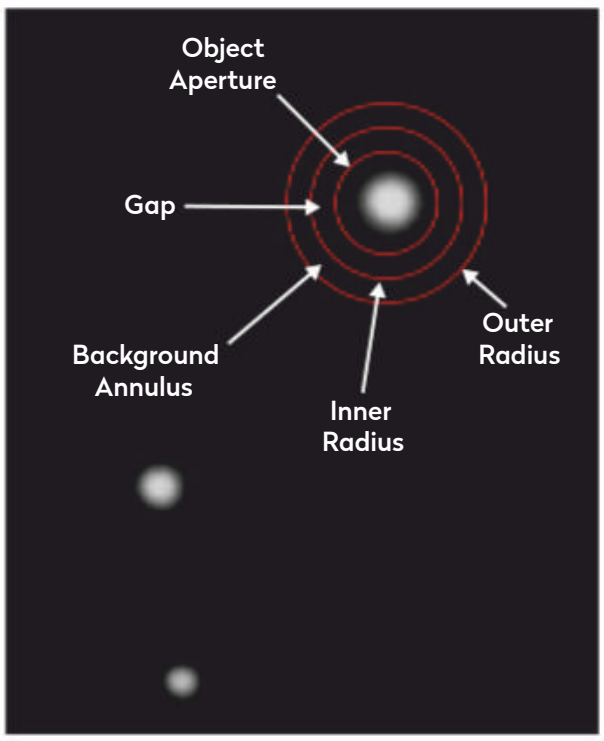


▲ **Determining the linearity and saturation point of a sensor. Use photometric-enabled software to determine the ADU of your CCD**



▲ **Johnson/Cousins filter transmission curves, V being most commonly used**

Photometry is the science of measuring light. The light received from a source object such as a star is recorded on a camera's chip and ultimately converted into an image. The data behind the image holds a value that can be used to work out a star's brightness. Objects such as variable stars have magnitudes that vary over time. Photometry can be used to determine accurate variable star magnitudes by comparing the variable's image with that of fixed-magnitude comparison stars.



◄ **Use and stick to a consistent aperture for all stars when measuring star brightness**

For accuracy it is important to deduce the noise contribution from your camera's electronics, the spectral response of your camera's sensor and optical factors from your telescope's optics and the atmosphere you're imaging through.

A CCD's response to light is linear. Blooming occurs when a pixel over-saturates. Typically this produces a cascade of charge from one pixel to the next, resulting in line artefacts spreading out from the star. CCDs with anti-blooming gates (ABG) correct this issue but truncate the CCD's linear response. Exposing below the saturation limit for an ABG sensor still allows it to be useful for photometry.

Serious photometric study involves the use of standard filters, the most common being those developed by Harold Johnson and Alan Cousins. Often used by amateurs is the Johnson V filter, which produces results similar to visual observations. Also available are Johnson B, Cousins I, Cousins R and Johnson U, listed in order of usefulness.

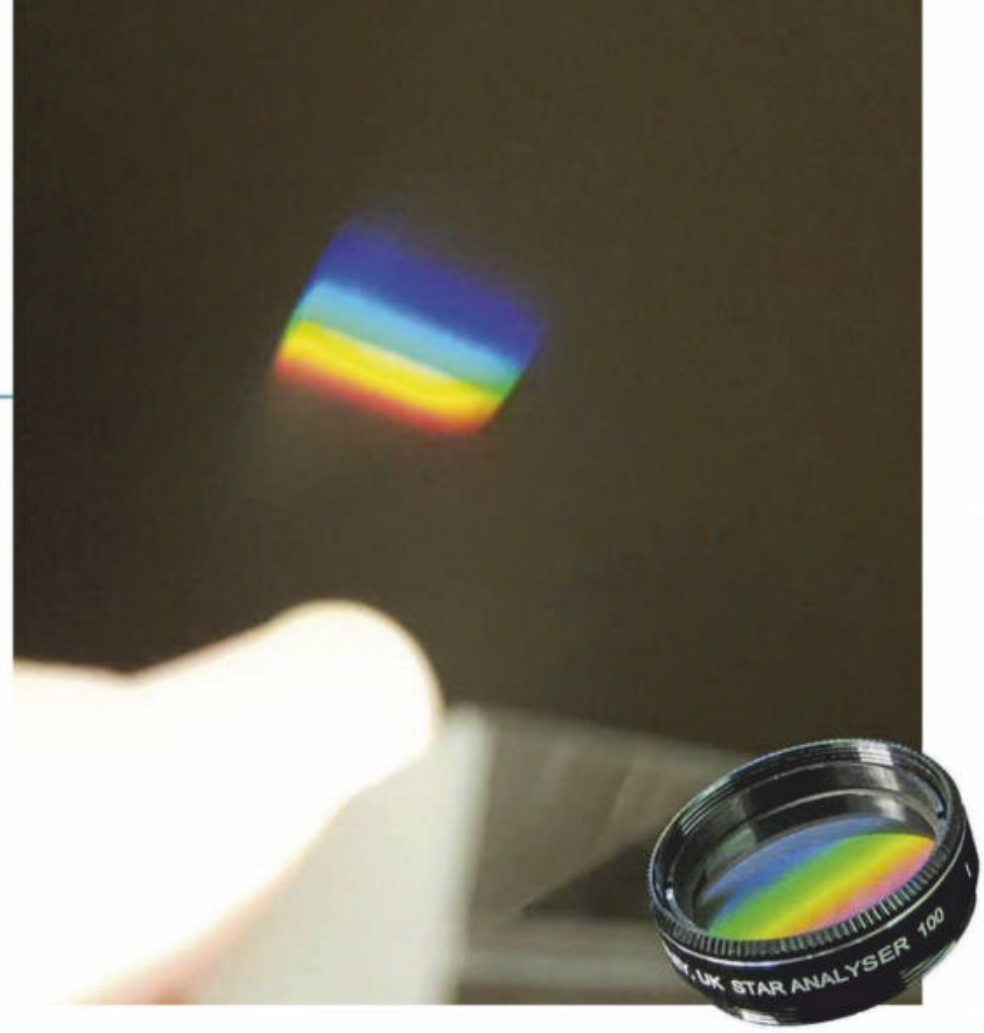
Images for photometric analysis should be calibrated. Once acquired, they should also be checked for anomalies such as satellites, planes or even clouds. The stars in the image should be identified either using astrometric software (plate-solving) or by using photometric charts for specific variables.

Measurement of star brightness is normally performed using an 'aperture'. This comprises a central circle sized to contain all of the light of a star surrounded by an annulus or ring separated by a small gap. The same size aperture must be used to measure the variable and its comparison stars. ►

PROJECT 2

The colour OF STARS

Split light to reveal the hidden signatures of the stars



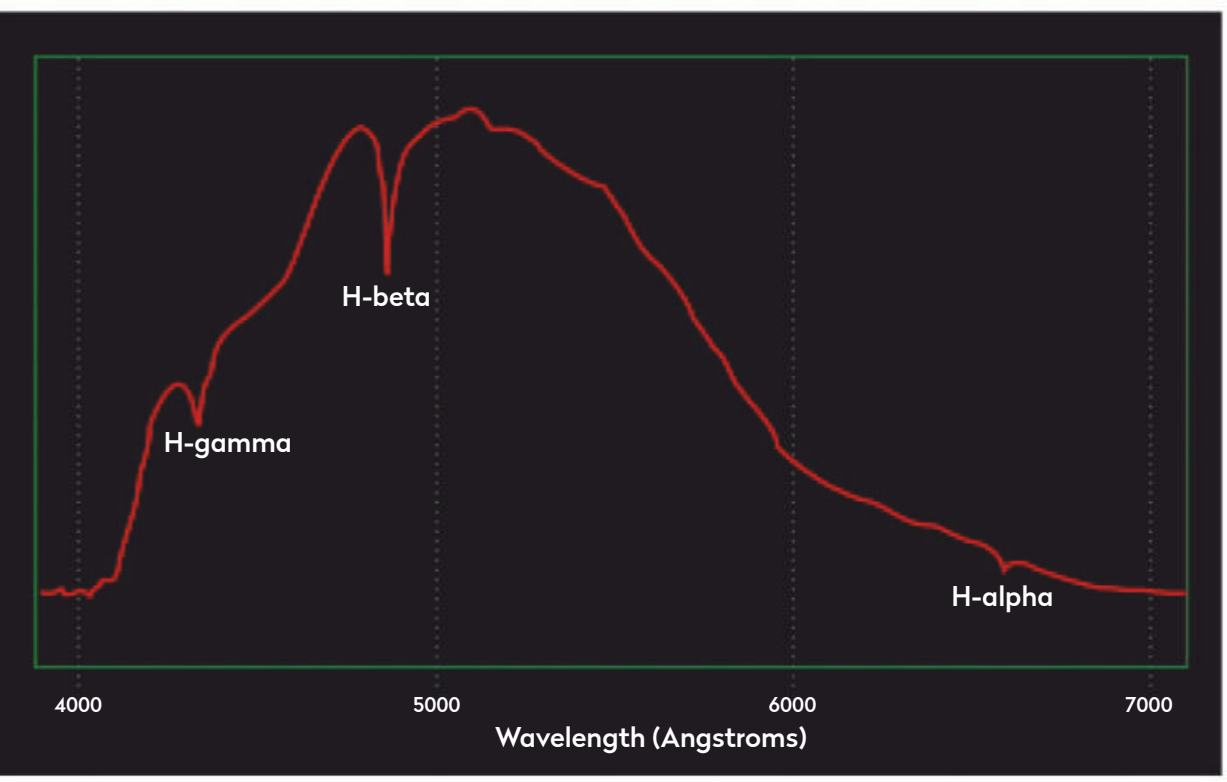
▲ **Using a glass prism for optical dispersion can be impractical. A better technique is to use a diffraction grating (pictured, inset), fitted like a conventional 1.25-inch filter, to disperse the starlight**

Astronomical spectroscopy is the science of analysing the spectrum of an object's light. It's an important and fundamental part of analytical astronomy that can yield very valuable results. Starlight is composed of different wavelengths of light. Passed through an optical dispersion device such as a diffraction grating or prism, the light is spread out into the object's unique spectrum. This 'signature' spectrum can tell us the temperature of the star's outer atmosphere and the chemical composition of the star's outer layers.

In addition, starlight interacting with another medium can produce variation in spectra over time and recording this in a rigorous scientific manner can make a significant scientific contribution. An excellent example of such an observation was during the last eclipse of binary Epsilon (ε) Aurigae in 2009–2011. Here the spectroscopy research done by non-professional astronomers helped uncover never-before-measured variations in the composition of the unknown object that eclipses the primary every 27 years.

Basic spectroscopy involves nothing more than a simple dispersion element added in front of a camera.

ALL PICTURES: PETE LAWRENCE



▲ **Graph based on the spectrum of the star Deneb (Alpha (α) Cygni)**

▲ **The limited colours that are visible to the naked eye explode into a wealth of information once the star's spectrum is unveiled**

One easy-to-use example is a product called Star Analyser, which is available as a 1.25-inch filter costing around £200. This fits in front of a camera and produces a spectrum for analysis using specialist software such as RSpec. The beauty of this system is that it can be used with a wide variety of cameras, including readily available DSLRs. The important thing to get right with spectroscopy is calibrating the results so they are not skewed by the equipment or conditions. This is where choosing the right analytical software becomes very important.

For advanced analysis, instruments with greater spectral resolution such as the ES0002-Lhires III, a high-resolution spectroscope from Shelyak Instruments, can be used. However, these devices will typically require a much higher investment.

PROJECT 3

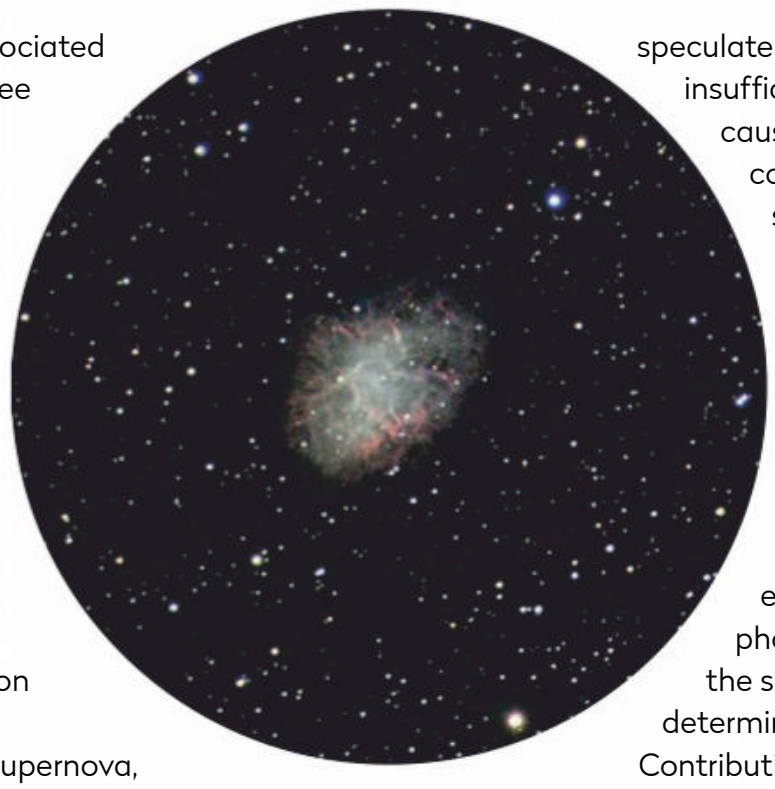
Supernova HUNTING

Scan the galaxies to catch stars dying and exploding

Supernovae are energetic outbursts associated with the death of certain stars. Only three have ever been observed in our own Galaxy, the last being in 1604. Most are detected in external galaxies. Even here, their occurrence is infrequent and the best way to detect them is by supernova patrols that systematically image a sequence of selected galaxies. The images taken are compared to the 'normal' view of the galaxies in the hope that a supernova appears as an extra star.

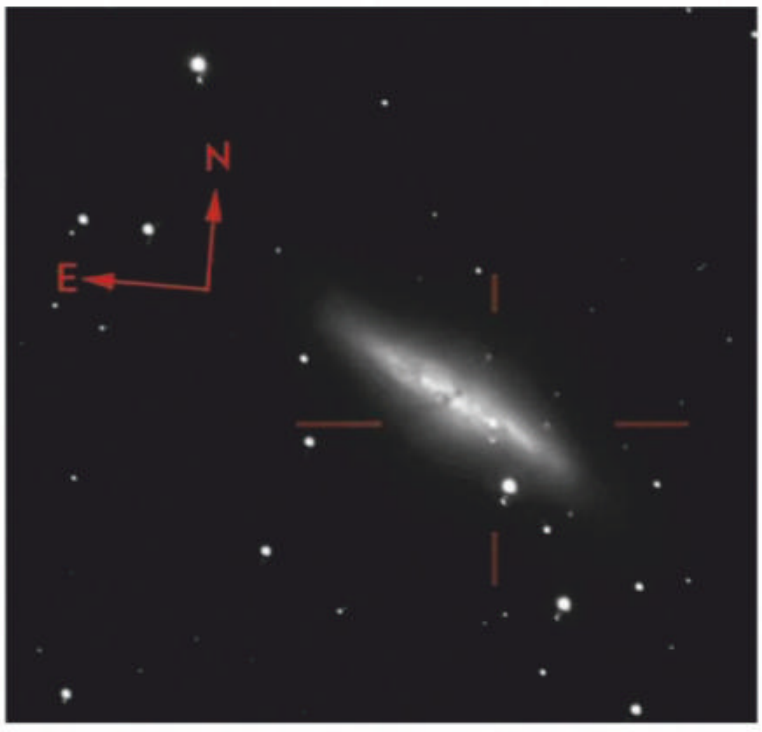
Should a supernova be detected, analysis of its light curve will, if done accurately, provide important information that allows the supernova type to be determined. There are various kinds of supernova, each having characteristic light curves that reveal the nature of the system that has exploded. Once identified, the application of photometric analysis (see Project 1) on a supernova will provide a lot of useful information about what actually happened.

A Type Ia supernova is thought to occur when a white dwarf star in a binary system accretes enough material from its companion to collapse. Some speculate that the accretion may be insufficient for total collapse, instead causing carbon fusion within the star's core. A non-standard Type Ia supernova describes the coalescence of two white dwarfs creating enough mass for collapse to occur. Type II supernovae occur when a massive star runs out of fuel. The core is unable to support the star's outer layers and collapse occurs, resulting in the star blowing itself apart. Further variations exist, making it extremely important to use accurate photometry to 'document' the profile of the supernova's light curve and so determine its type.

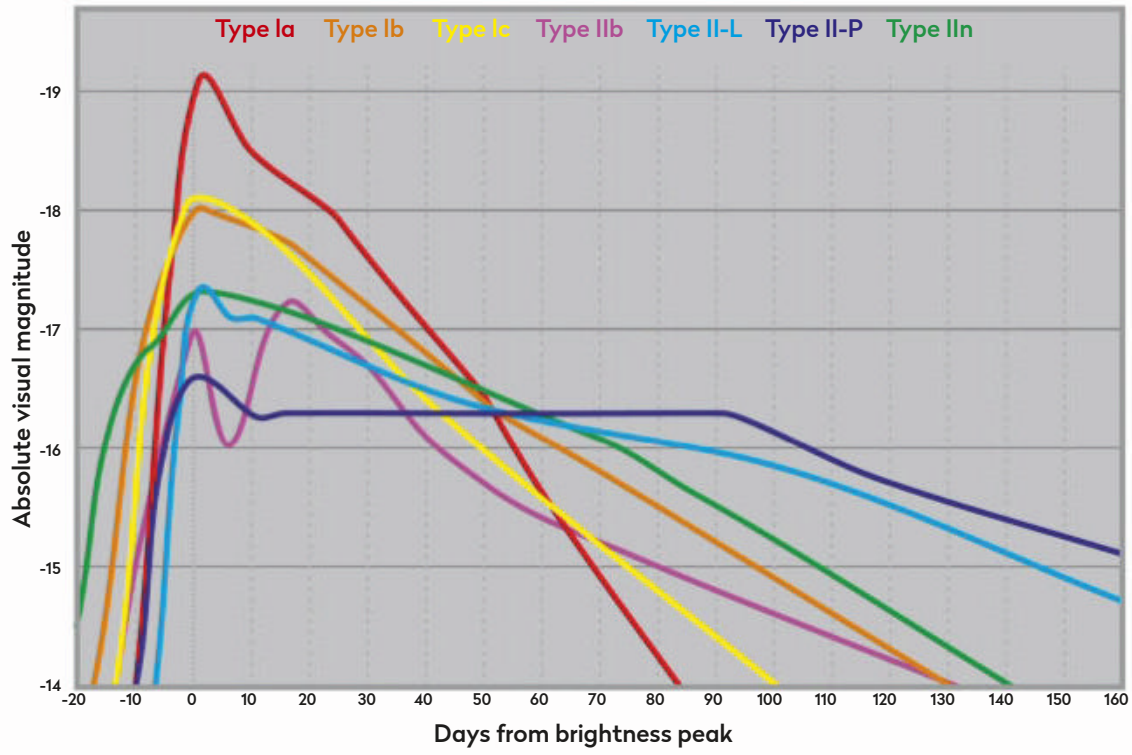


▲ Supernovae in our own Galaxy – like the one that produced the Crab Nebula, M1 (above) – are rare. The last was Kepler's Supernova in 1604

Contributing to supernova science doesn't necessarily involve a heavy investment in time or equipment. The Zooniverse website, for example, lets you check bulk collected galaxy images from the Pan-STARRS1 survey system without even owning a telescope. Visit www.zooniverse.org/projects/dwright04/supernova-hunters and see how you can contribute to this important area of astronomical science.



▲ Supernova SN 2014J, a Type Ia supernova discovered in M82, the Cigar Galaxy in January 2014



▲ Using photometry to reveal the distinctive light curve of a supernova will allow you to identify the type of system that has died

Practical astronomy projects for every level of expertise

DIY ASTRONOMY

Build a smartphone holder

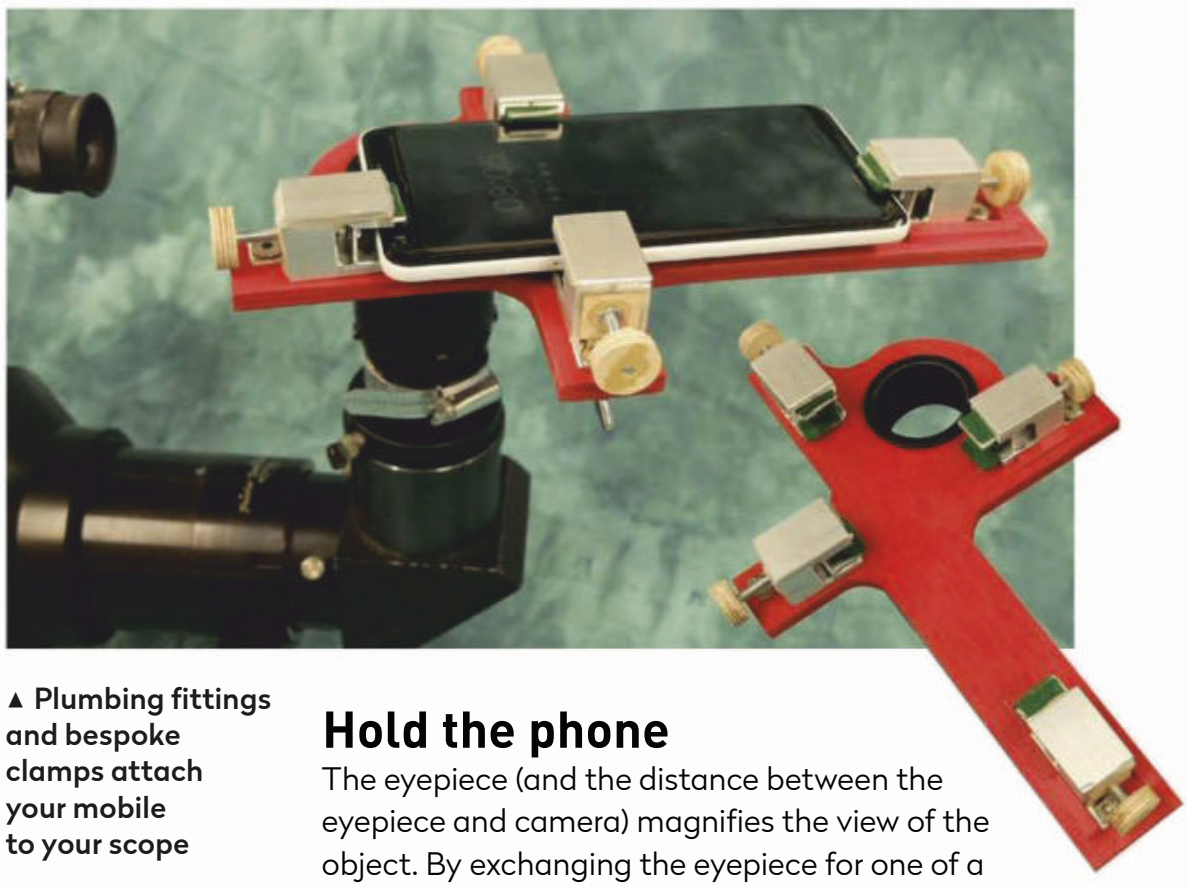
A homemade accessory for astro imaging with your smartphone

This month's project is an accessory that will help you to take great astrophotos using the camera on your smartphone. Unlike some commercially made versions, our design can be adapted to suit a wide range of phone models.

The method of imaging used is called 'eyepiece projection' or 'afocal projection' because it involves taking a photograph through a telescope's eyepiece (unlike 'prime focus photography' where the camera replaces the eyepiece). The camera lens must be firmly supported in a similar position to the eye when visually observing. This is where our adaptor comes into play.

The phone is held between two pairs of clamps mounted on a rigid baseplate. This has a nosepiece which securely inserts into a tube that clamps to your scope's eyepiece. These two parts are made from plumbing fittings: a push-fit straight connector and a blanking plug for 40mm PVC pipe. This means that it is easy to attach and remove the whole unit without any fiddling about in the dark. The clamps have thumbscrews and are spring-loaded, facilitating small adjustments to the alignment, allowing you to centre your phone's lens precisely over the eyepiece.

ALL PICTURES: MARK PARRISH



▲ **Plumbing fittings and bespoke clamps attach your mobile to your scope**

Tools and materials

▶ A hack saw, tenon saw or similar; drill and bits for screws; a 40mm bit for nosepiece hole; files

▶ A small sheet of good quality 6mm plywood (about A4 size); short lengths of 20x10x1.5mm and 15x15x1.5mm aluminium channel

▶ Four M4 x 40 CSK or flathead screws; four M4 Nyloc nuts and washers; two M4 nuts; four M5 x 16 (or 20) CSK screws with washers and wingnuts; push-fit PVC plumbing fittings: Floplast 40mm x 40mm straight connector and socket plug; small compression spring (cut in half) to fit over M4 screws; 40mm Jubilee clip; a small quantity of felt/padding material; epoxy resin glue

▶ Some spray paint for the base plate

Mark Parrish is a bespoke designer. See more of his work on his website: buttondesign.co.uk

More **ONLINE**

Download plans, diagrams and more photos for this project. See page 5 for instructions

Hold the phone

The eyepiece (and the distance between the eyepiece and camera) magnifies the view of the object. By exchanging the eyepiece for one of a different focal length, the size of the image can be varied. Large magnifications do result in dimmer and fuzzier images, so this technique is best suited to bright objects under good conditions.

Our prototype was designed around a Google Phone 2, which has a fairly large case, but by slightly modifying our downloadable plans you can adapt the design to suit any phone of up to 12mm thick (adjust the amount of soft padding inside the clamps to grip your phone). We found it helpful to attach the finished clamps to our phone and draw around them on a scrap of card to check their positions before cutting out the plywood base plate. Many phones have their lens behind the top right corner of the screen, but if your phone is different it should be easy to adapt the layout of the base plate to suit.

We fitted our plumbing connector eyepiece tube to a 12mm Plössl, but we found that most of our standard Plössl eyepieces fitted well. You might consider buying and fitting a few of these inexpensive tubes to a selection of your eyepieces so you can experiment during an imaging session without having to unscrew anything.

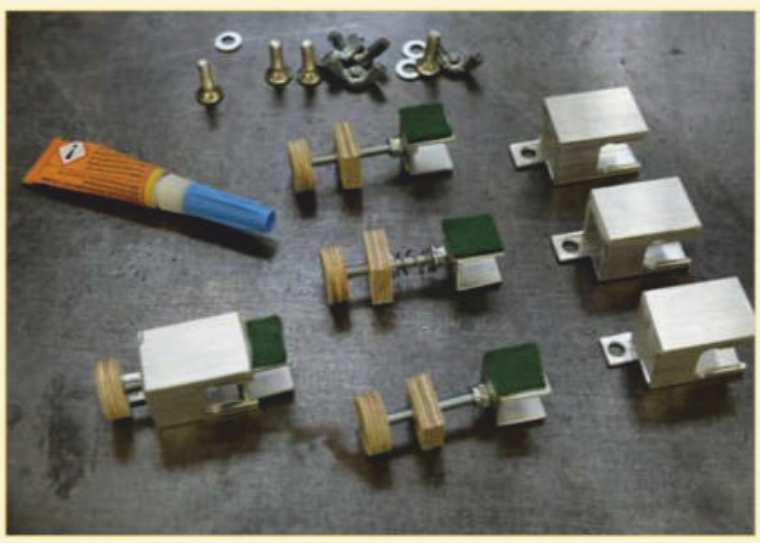
Step by step

Step 1

Print out the downloadable plans and use them to mark out and cut the aluminium channel. Use the drill, hacksaw and files to produce the required shapes. Make sure there are no rough edges before gluing anything together.

Step 2

Glue the two sides of each clamp together. We added an extra top layer of aluminium to increase overall strength. Cut the inner blocks and knobs from plywood and drill to fit the nuts and screws. To obtain the springs we cannibalised an old pen.



Step 3

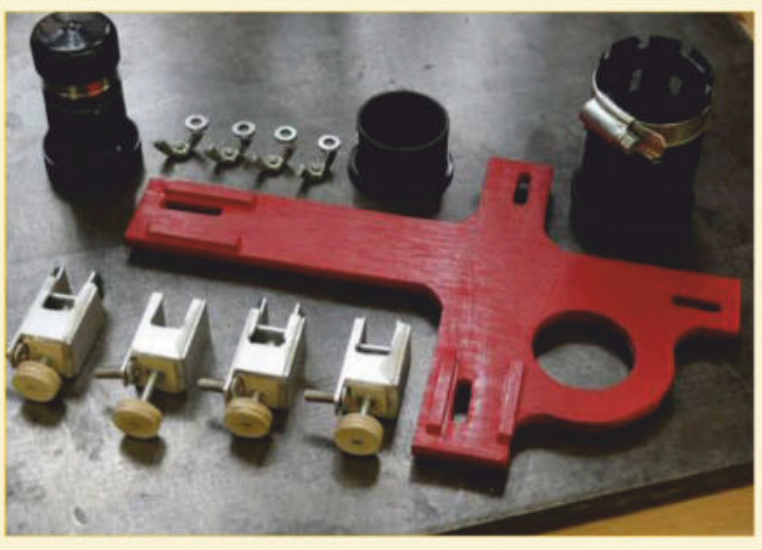
Assemble the inner parts of each clamp, checking that all fit and operate properly. We added thin felt inside the inner clamping section so it moved smoothly but without being loose. When you are happy, glue the blocks into the outer case.

Step 4

Draw out the shape of the base plate onto your plywood. After checking the layout with your clamps and phone, carefully cut it out and smooth the edges. Create the slots by drilling a row of holes then filing smooth. Add small strips to create guides.

Step 5

Paint the base plate then cut the PVC plumbing parts. Remove the blank end of the socket plug. Pull off the ring and O-ring from one end of the connector then cut a series of slots. These will compress around the eyepiece with a Jubilee clip.



Step 6

Loosely fit the clamps (fully tighten them once the phone is in its best position). Glue the nosepiece into the base plate. Attach the eyepiece holder to an eyepiece with a Jubilee clip, then fit the phone and push the nosepiece into the holder.

ALL PICTURES: MARK PARRISH

APOLLO 9

In the run up to the 50th anniversary of the Moon landing, **Elizabeth Pearson** traces the pioneering Apollo missions that paved the way

The Apollo astronauts knew better than anyone that landing on the Moon was always going to be a formidable challenge. When the crew of Apollo 9 – Commander James McDivitt and pilots Russell Schweickart and David Scott – blasted into low Earth orbit on 3 March 1969, the G-force pressing down on their bodies was not the only pressure they were under.

Two months earlier, the Soviets had docked two modules in space. To NASA, this was a clear precursor to a manned lunar landing, despite official Soviet pronouncements that there were no plans to put a Russian on the Moon (in fact, there were at least two Soviet lunar programmes and both were in chaos).

In December 1968, Apollo 8 – the first crewed circumlunar flight – had pulled the US into the lead for the first time since the beginning of the Space Race. They couldn't afford to fall behind now. With the clock running down on meeting the "end of this decade" deadline for a lunar landing set by President John F Kennedy, NASA had lined up a gruelling schedule of five Apollo missions throughout 1969, with the earliest chance of a landing being the third.

If Apollo 9 didn't go to plan, the whole timeline would be at risk. And the crew knew it. There was little room for error, especially as the mission was testing one of the most important parts of the entire project: the lunar module that would carry the moonwalkers to the surface.

In the Saturn V's launch configuration, the Apollo lunar module was stored behind the command module, where the crew would live for most of the time during missions. It needed to be extracted from the upper stage before the mission could progress. Work began on this task as soon as Apollo 9 entered orbit. After a few hours, the crew undocked the

NASA X 10

MISSION BRIEF

Launch date: 3 March 1969

Launch location: Launch Complex 39 A

Orbits: 151

Furthest distance from Earth: 497km

Duration: 10 days, 1 hour, 54 seconds

Return date: 13 March 1969

Main goals: Test lunar module; rehearse lunar module docking; rehearse emergency rescue spacewalk

Firsts: Crewed lunar module flight; lunar module docking on orbit; spacewalk on lunar module.

Menu: Shrimp cocktail, beef and vegetables, cinnamon toasted bread cubes (8), date fruitcake, orange-grapefruit drink

Meet the astronauts

Commander: James McDivitt
Born 10 June 1929, air force pilot McDivitt joined NASA in 1962. After flying the Gemini 4 and Apollo 9 missions, he took over managing the Apollo programme in August 1969, just after Apollo 11. In 1970 he helped guide the crew of Apollo 13 through the emergency procedures he himself rehearsed during Apollo 9.

Command module pilot: David Scott
Texan Scott, born 6 June 1932, initially dismissed Apollo as a pipe dream. He joined NASA's third class of astronauts in 1963 and flew with Neil Armstrong on Gemini 8, a mission which nearly ended in disaster when a stuck thruster sent it spinning. In 1971 he became the seventh person to walk on the Moon.

Lunar module pilot: Russell 'Rusty' Schweickart
Born 25 October 1935 in the aptly named Neptune, New Jersey, fighter pilot Schweickart joined NASA in 1963. After Apollo 9, he took part in a study on space sickness before transferring to the Skylab project, but never flew in space again. In 2002, he co-founded a foundation to raise awareness of the threat of asteroid impacts.

> Man, this is going to be a long, hungry day. I can feel it already – Russell Schweickart

command module, called Gumdrop, from the booster stage before flipping around and docking with their lunar module, named Spider.

After a day of testing the combined spacecrafts' manoeuvrability, everything seemed to be going well. It was only on the third day, as the crew prepared to cross over to the lunar module, that things began to go wrong for the module's pilot, Schweickart.

Knowing he was susceptible to motion sickness,

...but eventually overcame his nausea to complete a successful spacewalk

▼ Schweickart, pictured here in Apollo 9's command module, suffered from motion sickness at the start of the mission...

Schweickart had spent his first two days in orbit holding his head still to prevent himself feeling ill in microgravity. Unfortunately, in doing so, he'd also stopped his body adapting.

As he suited up to head over to the lunar module, he was forced to bend over while contorting himself into his spacesuit, and motion sickness struck.

Being sick is unpleasant at the best of times, but in microgravity it can be a serious safety hazard. Schweickart was due to make the first spacewalk of the Apollo programme with commander McDivitt the next day. If he vomited inside his suit, he would certainly choke.

Spacewalk in jeopardy

The spacewalk was designed to test the manoeuvres needed for astronauts to crawl across the outside of the lunar module to the command module, as they might have to do if there was a problem with docking while returning from the Moon. It was an important safety test. Without it, the mission may have to be repeated, pushing back the lunar landing by another two months.

But when Schweickart was ill a second time, Commander James McDevitt had no choice but to cancel the spacewalk. Thirty years later, the lunar module pilot told NASA historians that night was one of the lowest points in his life.

"I had a real possibility in my mind at the time of being the cause of missing Kennedy's challenge of going to the Moon and back by the end of the decade," said Schweickart. "Getting to sleep is never an easy task in space, but it was particularly difficult that night."

But sleep he did, and when he woke up Schweickart felt much better. McDevitt saw the change and, equally feeling the pressure to deliver a successful mission, put the spacewalk back on the schedule at the last minute. ▸

Scott stands in the hatch of Apollo 9's command module, nicknamed Gumdrop

▸ The spacewalk was truncated from two hours down to just 47 minutes, but that still left enough time to test moving around using the handrails on the lunar module's exterior, proving it would be possible to do so safely.

Cast into space

With spacewalk success achieved, it was time for the lunar module, with McDivitt and Schweickart on board, to go it alone. The next day, they prepared to detach Spider, and drift away into space.

To the public eye, this seemed an incredibly dangerous prospect. If there was a problem, the pair could end up stranded. And Spider's appearance did little to instil confidence. During an early visit to the lunar module's manufacturer, McDivitt ridiculed what he assumed was a test model for being made of "cellophane and tin foil put together with Scotch tape and staples". He was horrified to learn it was a flight-ready model.

Though improvements had been made to the module in the years since, several panels had come

> You're the biggest, friendliest, funniest looking Spider I've ever seen – Scott, welcoming back the lunar module

The lunar module, dubbed 'Spider', performed perfectly despite its flimsy appearance

NASA X 6, ILLUSTRATION BY PAUL WOOTTON

Dr Elizabeth Pearson is *BBC Sky at Night Magazine*'s news editor. She gained her PhD in extragalactic astronomy at Cardiff University

MISSION TIMELINE

3 March 16:00
Apollo 9 launches from Kennedy Space Center.

3 March 18:41
The command module undocks from Saturn V's booster stage and turns around.

3 March 19:01
The command module docks with, then extracts, the lunar module, Spider.

5 March 11:15
Schweickart and McDivitt cross over into the lunar module. Schweickart begins to suffer from space sickness.

6 March 16:59
Spacewalk starts. Lasts 47 minutes.

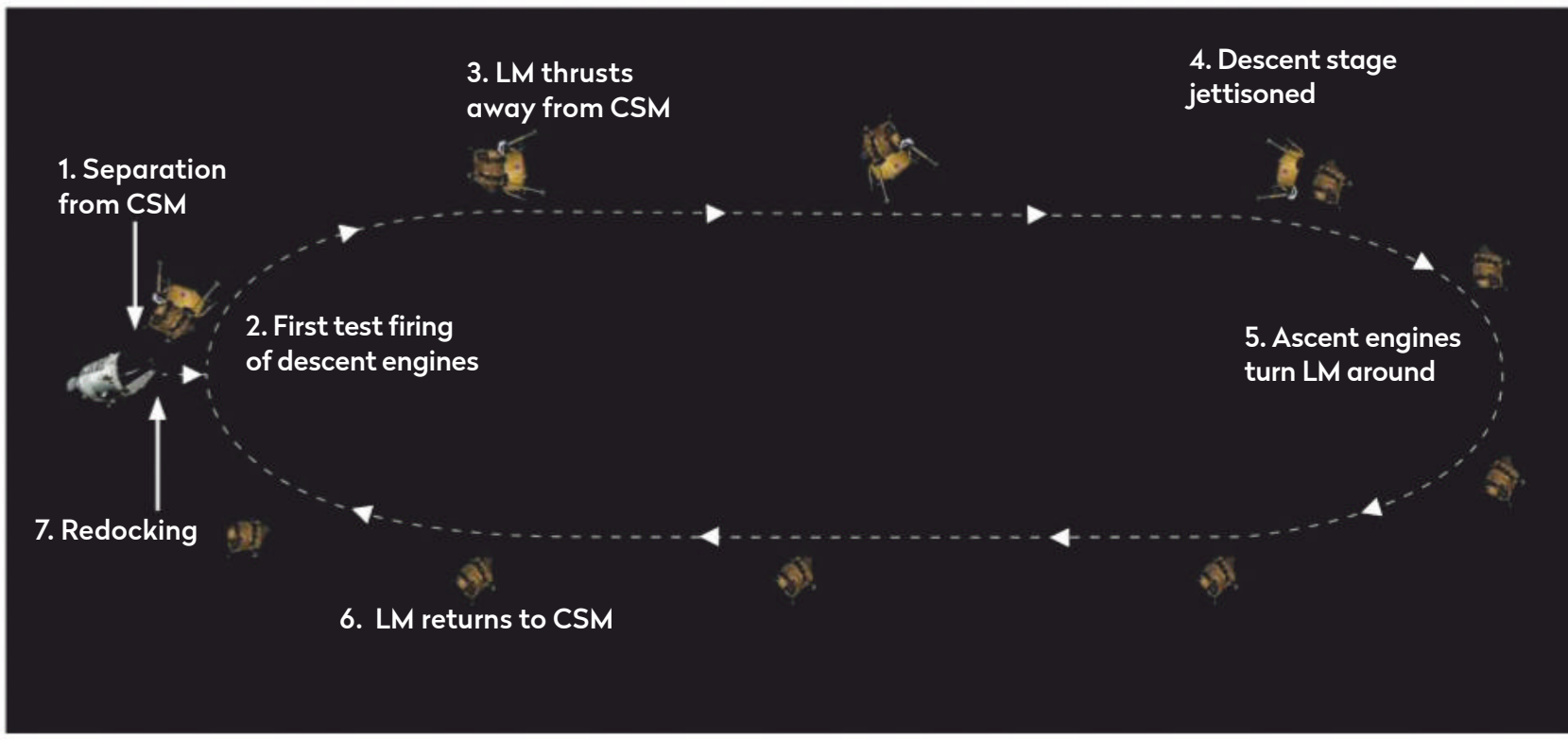
7 March 12:39
Spider undocks from the command module. Descent thrusters carry it over 150km away. The module jettisons the descent stage.

7 March 19:02
Over six hours later, Spider uses ascent thrusters to return to and redock with the command module.

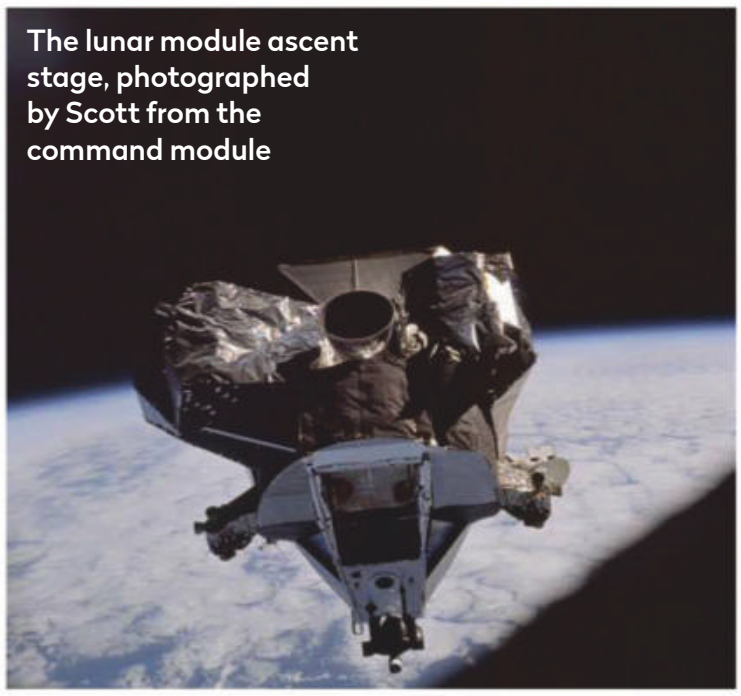
13 March 17:00
The return capsule splashes down in the Atlantic Ocean.

23 October 1981
Lunar module descent stage reenters Earth's atmosphere.

All times are GMT.



▲ In a space first, Apollo 9's lunar module (LM) flew 150km before redocking with the command module (CSM)



The lunar module ascent stage, photographed by Scott from the command module

Scott would go on to command the successful Apollo 15 Moon landing

loose during launch, leaving things in quite a mess. "I bet you there's not 50 per cent of the things over there [in Spider] that work," said McDivitt.

But after months of simulations, the pair were confident in their ability to complete the task. David Scott aboard the command module released Spider into space. It backed away to a safe distance of around 3km, where Schweickart test fired Spider's descent engines, designed to gently lower future landers to the Moon's surface. Spider was carried 150km away from Gumdrop before jettisoning the descent module, the part that would remain on the lunar surface during landing missions. McDivitt and Schweickart then test fired the ascent engines, which sent them back to the command module where they safely redocked, establishing that the lunar module worked as expected.

The crew remained in orbit another five days to mimic the time it would take to return from the Moon, keeping busy with systems checks and Earth observations. While the mission's main objectives had been achieved, the tight schedule still allowed little chance to eat and sleep. Indeed, like several other astronauts, lunar travel demanded too much of Commander McDivitt and following Apollo 9 he gave up his dreams of reaching the Moon himself. Instead, he would help his friends get there, including Scott.

"It was easy to burn out on missions," Scott said in his biography. "The great NASA team made them look easy. They were really, really hard."

Take the perfect astrophoto with our step-by-step guide

ASTROPHOTOGRAPHY CAPTURE

PETE LAWRENCE X 4

▲ **If geomagnetic conditions are right, on clear, dark nights it may be possible to see the aurora over parts of the UK**

Photograph the aurora from the UK

Get ready for the chance to catch the Northern Lights this month

Spotting and photographing the aurora borealis (the Northern Lights) from the UK is an interesting pastime. It's something that's undoubtedly easier to carry out the further north you live. Auroral displays also tend to be larger, brighter and more frequent around the equinoxes, so the dark skies at the end of March 2019 and the start of April 2019 are a great time to try to photograph them.

The reason the aurora is easier to see the further north you live in the UK is simply that you are closer to the auroral oval. The oval is a name given to the band where the aurora normally performs. It typically spans about 10 degrees of latitude and is located vertically in the atmosphere from 80km to 250km. However, these are average values and can change with the nature of the space weather coming from the Sun. The oval can thin and shrink north under quiet conditions or thicken and move south when conditions are favourable. Its maximum height can also increase, taking its upper limits to altitudes of 500–800km.

Observing the aurora from the confines of the UK requires keeping a constant eye on space weather conditions. Major outbursts from the Sun create high anticipation, although if the conditions are wrong, little may be seen. It generally requires the aurora to undergo a boost in activity for it to become visible from the UK and the amount of boost dictates how far south it can be seen. The 'boost' can be predicted by a value known as the Kp-index, often just referred to as Kp. This is a weighted average of K-indices supplied by observatories monitoring fluctuations in Earth's magnetic field over three-hourly intervals. The index ranks that magnetic disturbance on a 0–9 scale.

Kp can be used to give a general indication as to how far south the aurora can be seen. For the northern isles, a Kp of 3–5 should be enough. For mainland Scotland, a Kp of 5–6 is required. A Kp of 6–7 will give northern England a chance, while 6–8 is required for the Midlands. For southern England to get a view, a Kp of 8–9 is normally required. These figures are not set in stone and a large auroral display which extends to the upper altitude limits may be seen further south than one that is not as vertically extensive.

Another figure to keep an eye on is Bz, the vertical (that is, at right-angles to the plane of the Solar System) component of the magnetic field carried by the solar wind. If Bz points north, there is little interaction between the solar wind buffeting Earth's own north-pointing magnetic field. If Bz swings south, both fields interact, opening up the possibility of a good auroral display.

If an aurora is suspected, it's essential to pick a dark sky location from which to try to see and photograph it. Auroral light is easily masked by light pollution. You may get lucky and see a full-on banded display – the type seen from locations under the auroral oval or in books on the phenomenon – but it'll probably appear more subtle. This is where your camera comes into play. The increased sensitivity of a camera chip makes it a great auroral light detector. Using a camera to confirm sightings is also fairly straightforward and a fascinating thing to do to get you that bucket list view from right here in the UK.

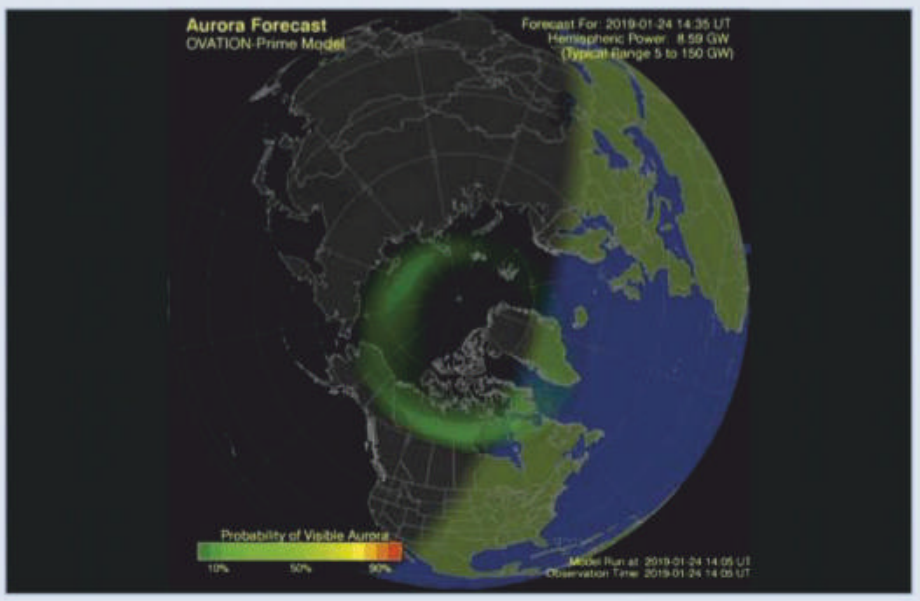
Pete Lawrence is an expert astro imager and a presenter on *The Sky at Night*

Recommended equipment: DSLR, wide and fast lens, tripod

Send your images to:
gallery@skyatnightmagazine.com

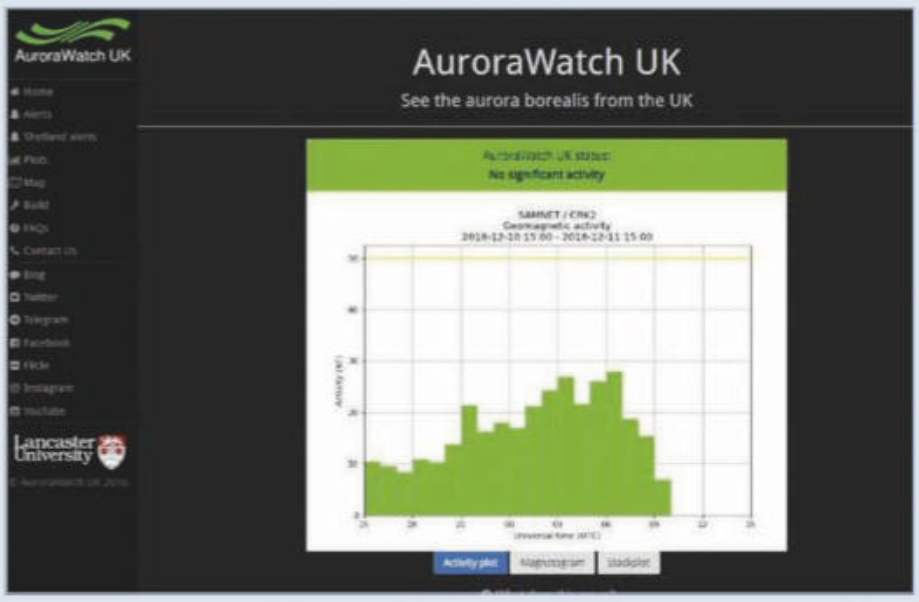
STEP 1

Various websites indicate geomagnetic activity and forecast auroral displays that may be seen in parts of the UK. The site spaceweather.com, for example, lists various data down its left-hand edge. It also reports regularly on potentially active conditions that may produce enhanced auroral displays.



STEP 2

If a display is predicted, keep an eye on the visual indication given by sites such as https://services.swpc.noaa.gov/images/aurora-forecast-northern-hemisphere.jpg. This is available via the spaceweather.com website, which also reports on the latest Bz measurement.



STEP 3

Another useful UK-oriented site is AuroraWatch UK: https://aurorawatch.lancs.ac.uk. Using simple colours, it indicates levels of geomagnetic activity and the likelihood that the aurora may be seen from the UK. It also offers an alert service that can automatically alert you when activity gets high.

STEP 4

If you suspect a display may occur, find a dark location with a low northern horizon. A DSLR on a fixed tripod can be used as a detector. A wide lens that allows you to cover a span from the northwest through to the northeast is recommended. Fully open the lens, set it to manual focus and set focus to infinity.

STEP 5

Use a mid to high ISO setting of 800–1600. Once the best exposure is determined, set the camera to continuous shooting and, using a remote shutter release, keep taking images one after the other. What you're looking for is auroral colour. Green is most common but weak reds, blues and purples are also possible.

STEP 6

If there is colour, it may be auroral. One verification method is to flick through your images looking for movement. If the colour remains static, it may be man-made. If it moves, then you might be lucky. Whether it brightens and becomes more obvious is then down to Mother Nature.

Expert processing tips to enhance your astrophotos

ASTROPHOTOGRAPHY PROCESSING

Peter's final processed image of IC 1318, shortlisted for Insight Investment Astronomy Photographer of the Year 2018

ALL PICTURES: PETER JENKINS

Insight Investment Astronomy Photographer of the Year

Advice from a 2018 shortlisted Deep Sky entrant

IIAPY Masterclass
Enhancing IC 1318, The Butterfly Nebula

PixInsight, Photoshop and Stratton combine for some processing panache

The 'dark art' of processing is not an exact science. There are so many techniques you can use and they're constantly evolving, which means that a lot of your choices are as much down to personal taste as technical know-how.

Here I'll describe the processing techniques used on my image of IC 1318 which was captured and processed during September 2017. I was very pleased with the results, so hopefully some of the methods I used will prove helpful for you.

IC 1318 is a beautiful and interesting area surrounding Sadr (Gamma (γ) Cygni), with fascinating details. The framing of the photograph was carefully chosen to include the central dust lane (running from bottom right to top left) and to exclude Sadr (just off frame to the left). At mag. +2.2, the exposure lengths needed for the nebula would have overexposed the star.

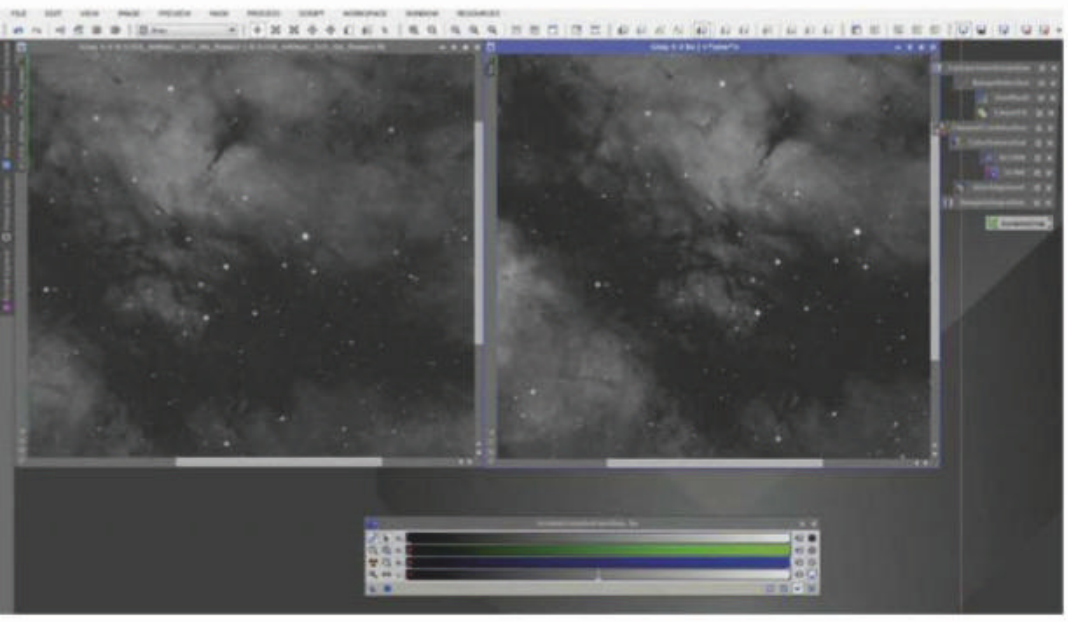
Using Sequence Generator Pro's framing wizard, the image area was chosen and a sequence of 12 x 600-second exposures (subs) was taken. My equipment was an Officina Stellare Hiper apo 115mm refractor with a Riccardi 0.79x reducer/flattener, an Atik 383L Plus CCD camera and EFW2 filter wheel fitted with Astrodon Ha, OIII and SII filters. A dark and bias library was used and flats were taken at the end of the sequence for each filter using an aurora flatfield panel.

I used PixInsight to calibrate the subs from all three filters using the dark, flat and bias library. The resulting calibrated subs were aligned and stacked using 'Windsorized Sigma Clipping' as the rejection algorithm for each filter set. The first stack of Ha subs was then cropped to remove any unaligned edges and the same crop applied to the other two stacked subs (OIII and SII).

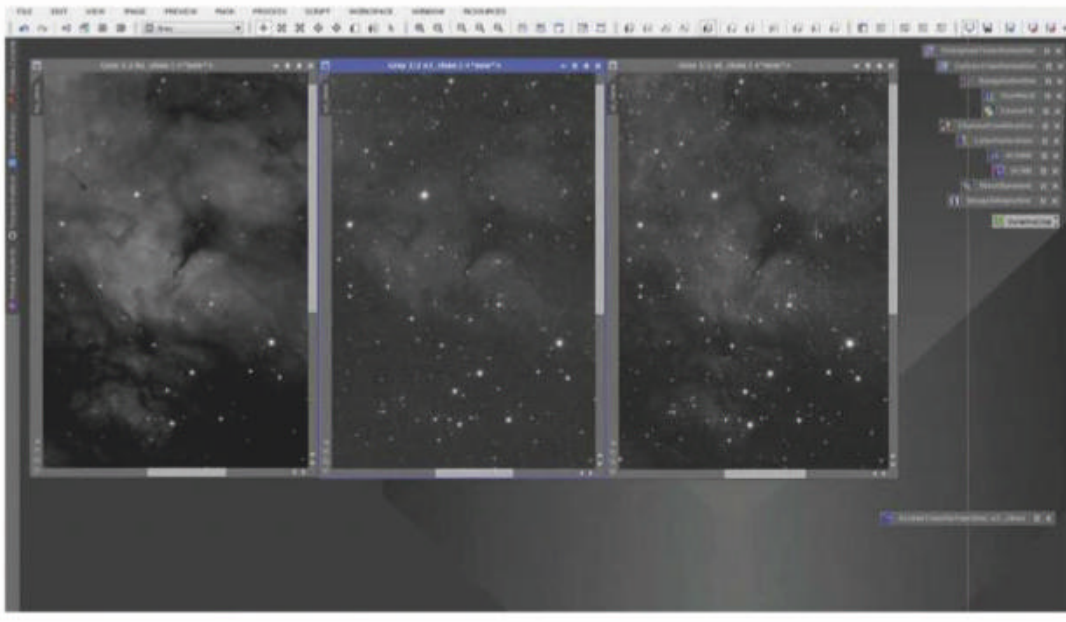
I then stretched a copy of each of the three images using Histogram Transformation and applied some further noise reduction using ACDNR (Adaptive Contrast-Driven Noise Reduction), with a lightness mask to protect high-signal areas. I then saved the three completed subs as 16-bit TIFF files.

Colour correction

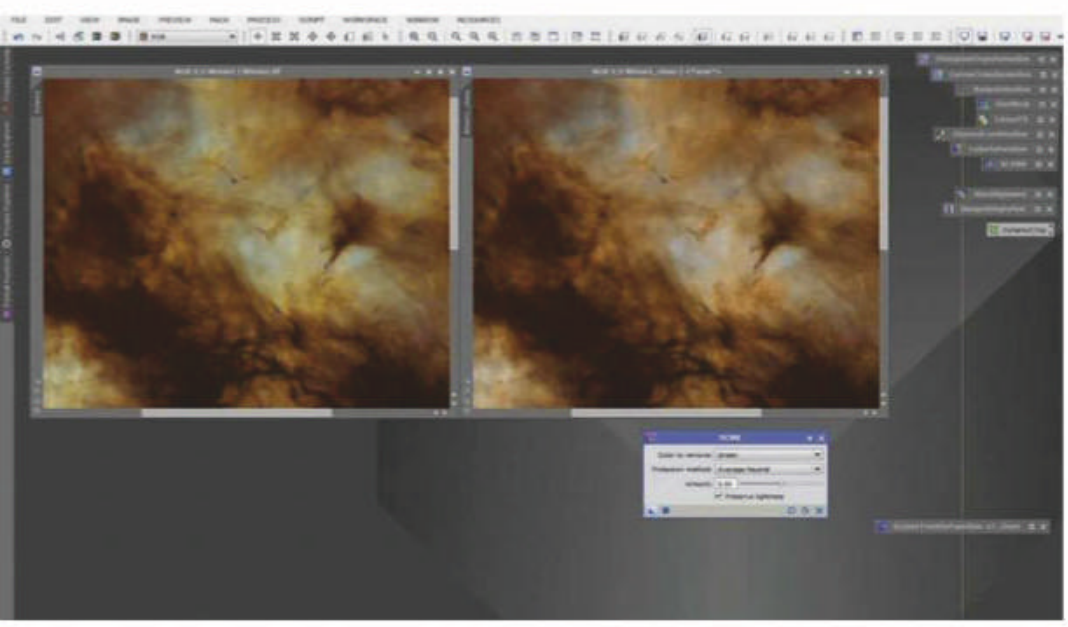
Stars imaged with Ha, OIII and SII filters (the Hubble palette) often have a magenta cast. To get white stars I had to remove the stars before creating the colour image and applying a luminosity layer. Separate RGB images of the stars can also be used to give a more natural star colour. There are a number of options for removing stars from images, but I find



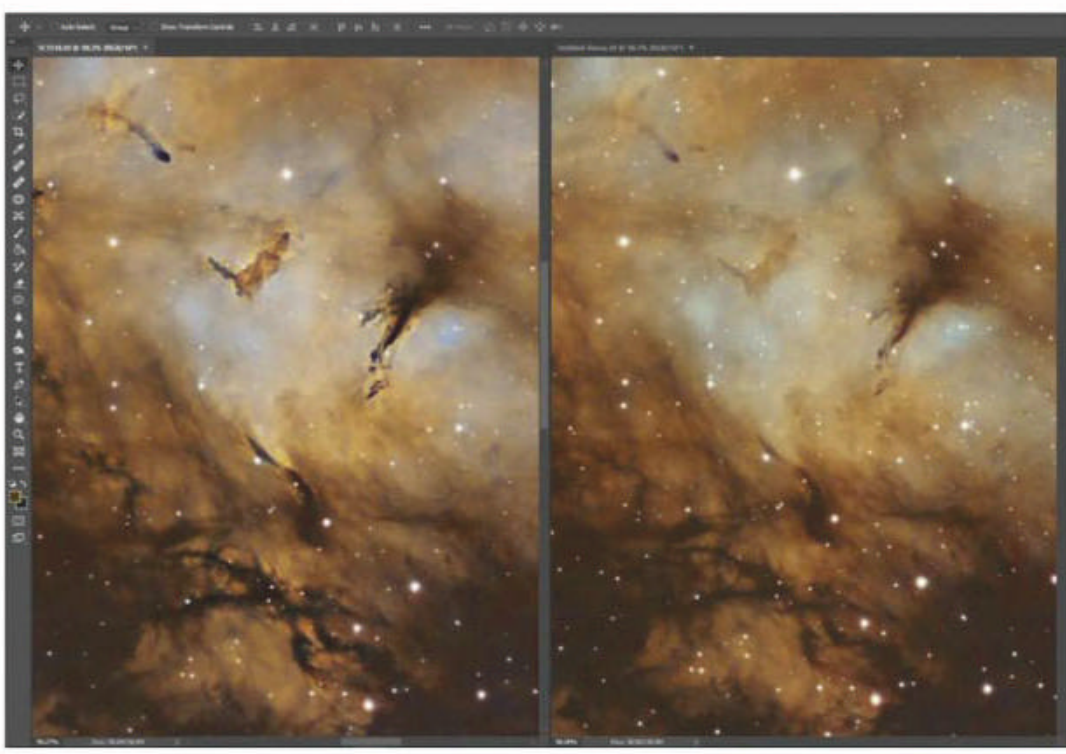
▲ Single 600-second Ha exposure (sub) as shot (left) and 12 x 600-second Ha subs stacked (right)



▲ Completed Ha, OIII and SII images in PixInsight before their export as TIFF files



▲ Detail of starless colour image showing the slight green cast and its removal in PixInsight (increased saturation for illustration)



▲ The effect of selective sharpening in Photoshop: sharpened (left) and unsharpened (right)

that the best results from my images are obtained using the inexpensive standalone software called Stratton. I used this to remove stars from each set and these were then saved as starless versions.

Next, I opened the starless images in Photoshop CC and used a Spot Healing Brush tool to remove residual traces of stars. The images were then adjusted using levels and curves (as a starless image can be further stretched without the risk of bloating the stars). Further noise reduction tackled dust and scratches and a minor Gaussian blur was used as these were for colour only and not to provide final image detail. I then flattened and saved the images.

The starless images were used as colour channels in a new RGB image, with Ha in the green channel, SII in the red channel and OIII in the blue channel. This provided a starless colour image which was then converted to the Hubble palette colours. Colour adjustments were made using the Selective Colour tool in Photoshop. In this case, after corrections the image still appeared to have a little too much residual green, so I opened a saved copy in PixInsight and applied the SCNR (Subtractive Chromatic Noise Reduction) process to reduce green by 50 per cent.

Peter Jenkins is a Fellow of the Royal Astronomical Society and has lectured on astrophotography at the International Astronomy Show

In Photoshop, a luminosity layer was created from the original Ha, SII and OII images (with stars) using the Ha as a base layer with SII and OIII images pasted on top as separate layers with the opacity reduced to 10 per cent in both cases. This combination of all three monochrome images provides more detail than using Ha alone as a luminosity layer. This was flattened, copied and pasted onto the colour image with the blending mode set to 'Luminosity'. Further minor adjustments were made using levels, curves and hue/saturation. Noel Carboni's Astronomy Tools (macro operation sequences that you load into Photoshop) was used to reduce the size of stars slightly.

A selective sharpening technique was applied with a high-pass filter (blending mode 'Overlay') and with a full mask. This mask can then be selectively painted using a soft white brush (50 per cent flow and 50 per cent opacity). Painting white into the mask slowly reveals sharpening only where required. This produced the final image, which was submitted and shortlisted for the IIAPY 2018 competition.

Your best photos submitted to the magazine this month

ASTROPHOTOGRAPHY GALLERY

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△ Orion widefield nebulous and dust goldmine

Ross Clark, Northumberland, 9, 10 December 2018

Ross says: "This was my first trip to a dark site with my Star Adventurer. I had planned to image just the Horsehead and Orion Nebulae at 200mm, but the wind was a little high so I brought it back to 70mm and included Barnard's Loop and the Witch Head Nebula. It's important to adapt to the conditions you find."

Equipment: Canon EOS 450Da DSLR camera, Canon EF 70–200mm f/2.8 lens, Sky-Watcher Star Adventurer mount
Exposure: 58x3' lights, 60x3' darks, 30x1/6" flats, 87x1/40000" bias
Software: PixInsight, Photoshop, Lightroom

Ross's top tip: "Understand what all your kit is for, exactly what it does and what its limitations are. There are several Facebook groups that are happy to help beginners with questions about equipment, imaging technique or processing. Also, spend as much time as needed getting both a polar alignment on an unassisted guide like the Star Adventurer and ensuring that your lens or telescope is pin-sharp in focus."

◁ Waning gibbous Moon

Andrew Brown, Lancashire, 24 December 2018

Andrew says: "I usually focus on imaging deep-sky objects, but as it was the 50th anniversary of the Apollo 8 Earth Rise image, I decided to capture our Moon. This is a two-panel mosaic."

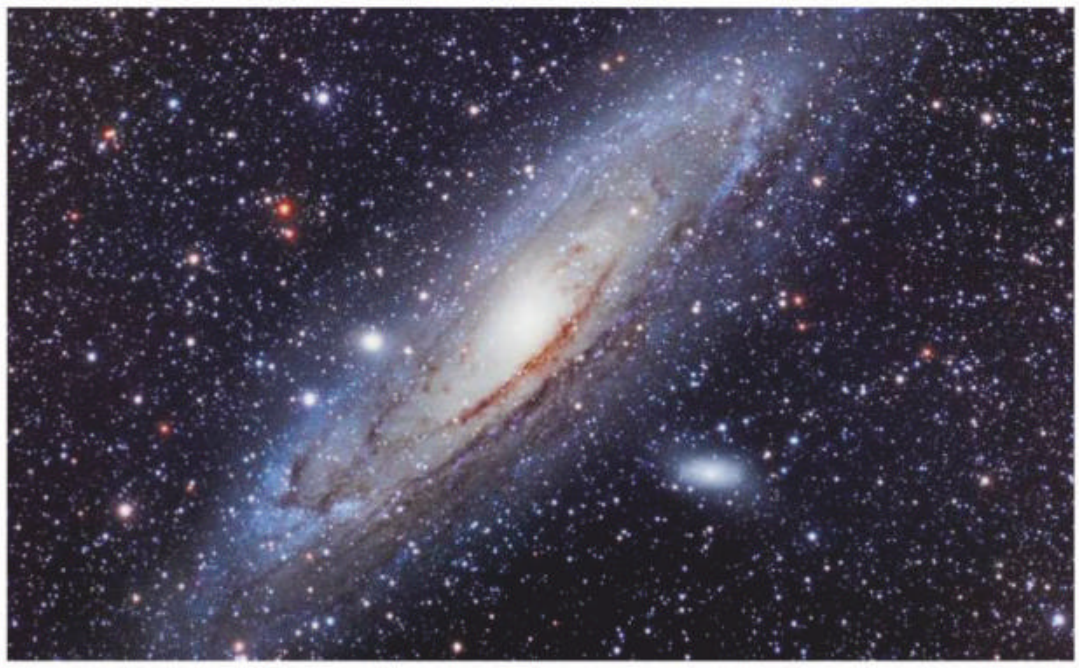
Equipment: Altair GPCAM2 290M mono camera, Explore Scientific ED80 apo triplet refractor, Sky-Watcher AZ GTi WiFi mount
Exposure: 1,000 frames
Software: SharpCap, Autostakkert!, Microsoft ICE, RegiStax, PixInsight

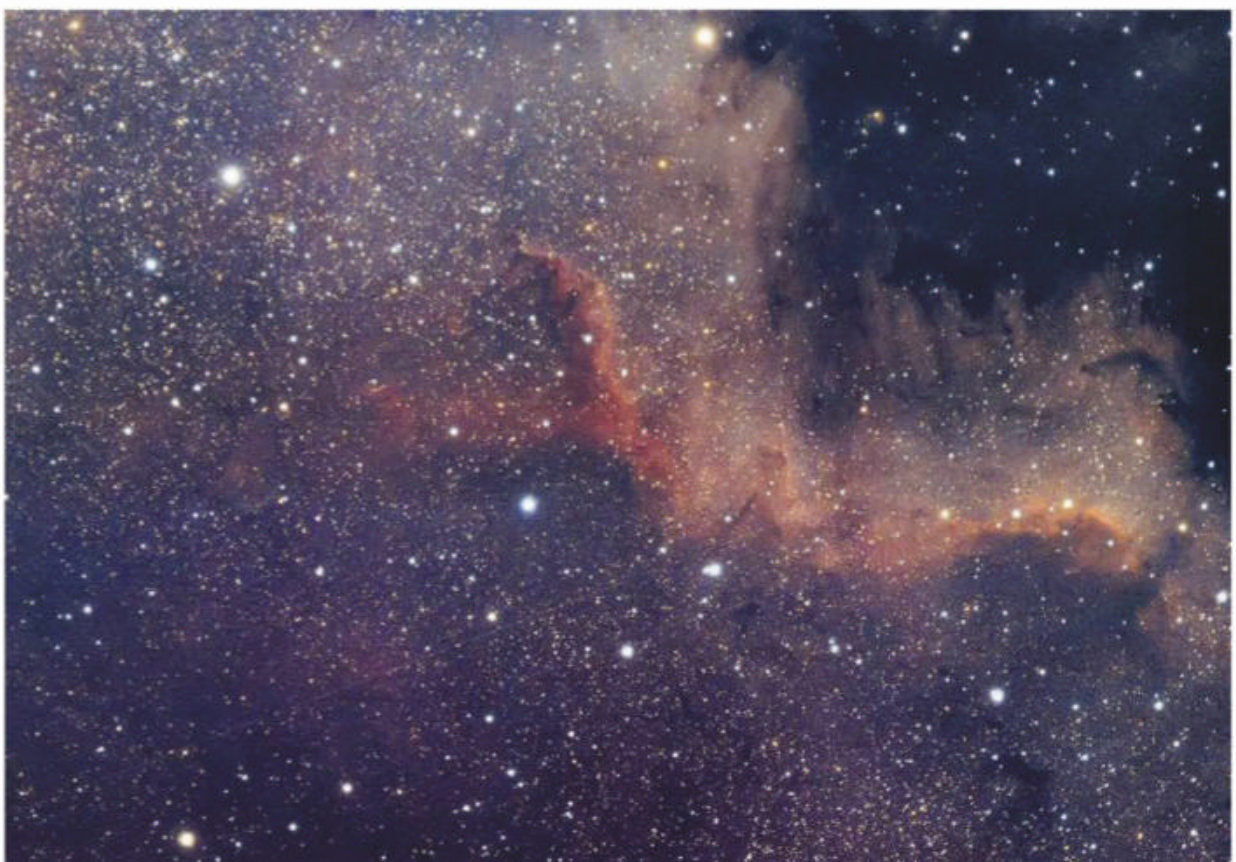
The Andromeda Galaxy ▷

Tim Cowell, Somerset, September 2018

Tim says: "Having moved to Somerset in 2018, I was eager to get first light from this new location. It's my third attempt at mono imaging so there was trepidation as I started the imaging run. I am pleased with the detail and brightness of the result, especially as my telescope is quite small."

Equipment: ZWO ASI1600MM Pro camera, William Optics Star 71 Mark II apo imaging refractor, Sky-Watcher AZ EQ6-GT mount
Exposure: 1h each LRGB and Ha
Software: Sequence Generator Pro, PixInsight, Lightroom





◁ Xi Cygni and Cygnus Wall

Stacey Downton, Birmingham, 14 August, 6 December 2018

Stacey says: "Originally this was a mosaic and I had cut out Xi Cygni to frame the whole North America Nebula. I wanted to give my image context so I reprocessed to include Xi Cygni which is visible with the naked eye."

Equipment: Altair Hypercam 183C Pro colour camera, Sky-Watcher Evostar 80ED Pro refractor, Sky-Watcher HEQ5 Pro mount
Exposure: 20x120"
Software: Astro Pixel Processor, Photoshop

◁ The Leo Triplet

David Newbury, Nottinghamshire, 4 December 2018

David says: "I wanted something that would just be rising so I could image through the night, as the weather forecast was fantastic. Looking at the charts I saw the Leo Triplet would be just on the eastern horizon."

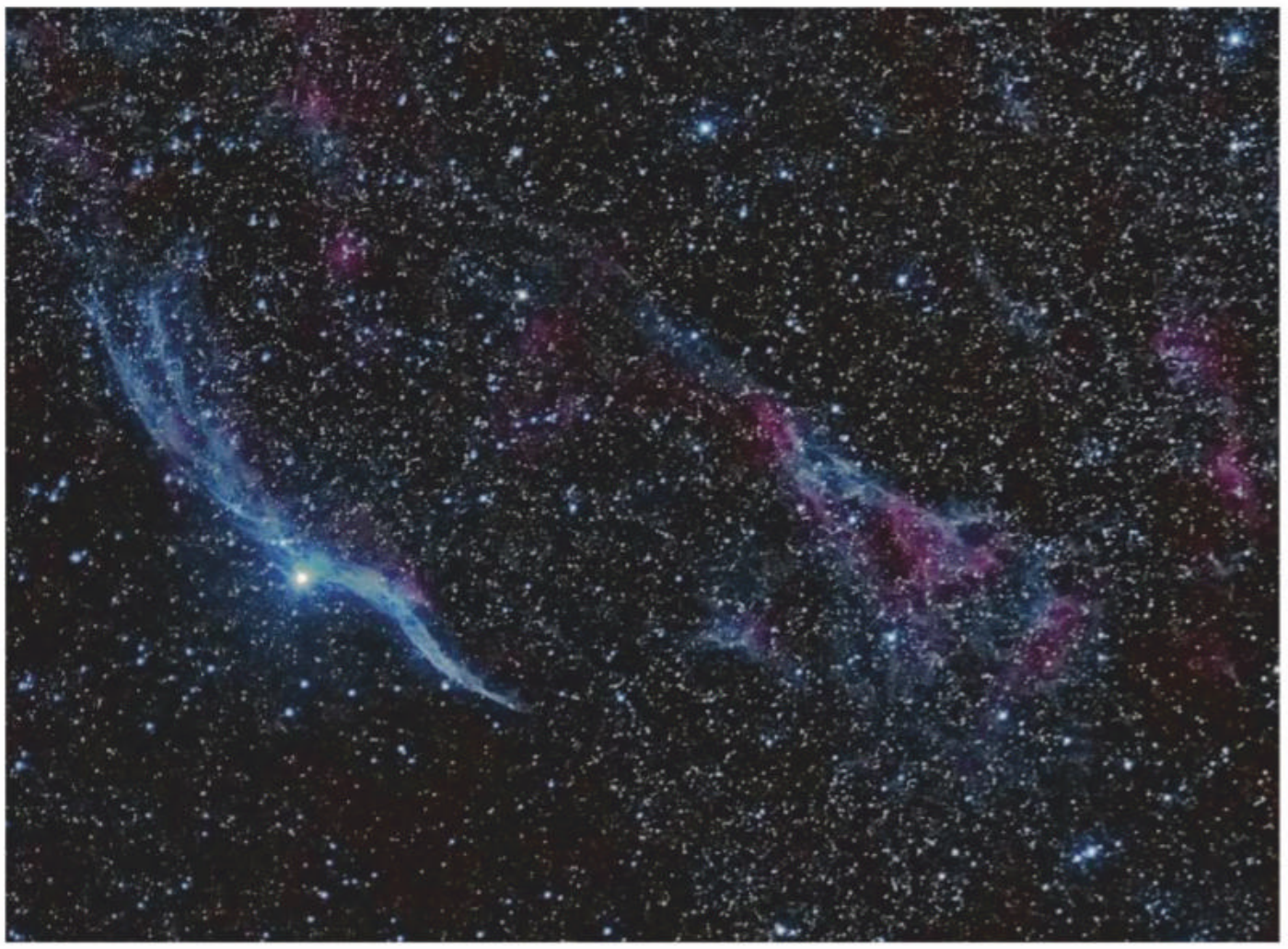
Equipment: ZWO ASI183MM Pro mono camera, TS-Optics Imaging Star 65mm f/6.5 quadruplet apo, Mesu Mount 200
Exposure: 12x120" RGB, 20x120" luminance
Software: PHD2, SGPro, PixInsight

◁ NGC 281

Steve Pastor, New Mexico, US, November & December 2017; October & November 2018

Steve says: "Although it's often imaged, I wanted to see how much detail I could see in the nebula in a bicolour image consisting of H-alpha and OIII. Since the OIII is much fainter I exposed longer using that filter."

Equipment: QSI683wsg mono CCD camera, Takahashi CCA-250 corrected Cassegrain astrograph, Paramount ME mount
Exposure: 5h20' H-alpha, 10h OIII
Software: MaxIm DL, PixInsight



◁ The Pleiades

Mindaugas Kausylas, Kryliai, Lithuania, 1 December 2018

Mindaugas says: "I had never imaged M45, but that night it just cleared the trees next to my house so I took advantage of the opportunity. I was impressed with the interstellar dust lanes, which look like ship sails to me and provide an artistic feel to the image."

Equipment: Nikon 5300 DSLR camera, Explore Scientific FCD1 80mm triplet apo refractor, Sky-Watcher HEQ5 Pro SynScan mount
Exposure: ISO 800, 29x210"
Software: DeepSkyStacker, PixInsight

△ The Veil Nebula

Marià Solé, Catalonia, 6 December 2018

Marià says: "Having completed the Messier objects, I decided to start capturing the Caldwell objects. The Veil Nebula is Caldwell 34. Previously I had trouble with time integration and focusing, but this time I was able to overcome such problems."

Equipment: Sony Alpha 7s DSLR, TS Optics 80/480mm apo refractor, Sky-Watcher HEQ5 Pro SynScan mount
Exposure: ISO 12800, 35x40"; ISO 40000, 22x40" CLS filter; ISO 40000, 15x40" H-beta
Software: DeepSkyStacker, PixInsight, ACDSee

△ Total lunar eclipse montage

Les Brand, Upminster, 21 January 2019

Les says: "I'd never captured a lunar eclipse before but had seen some amazing images from fellow astro club members. I decided to keep it simple with the bridge camera. Witnessing it from my back garden in -5°C was an amazing experience."

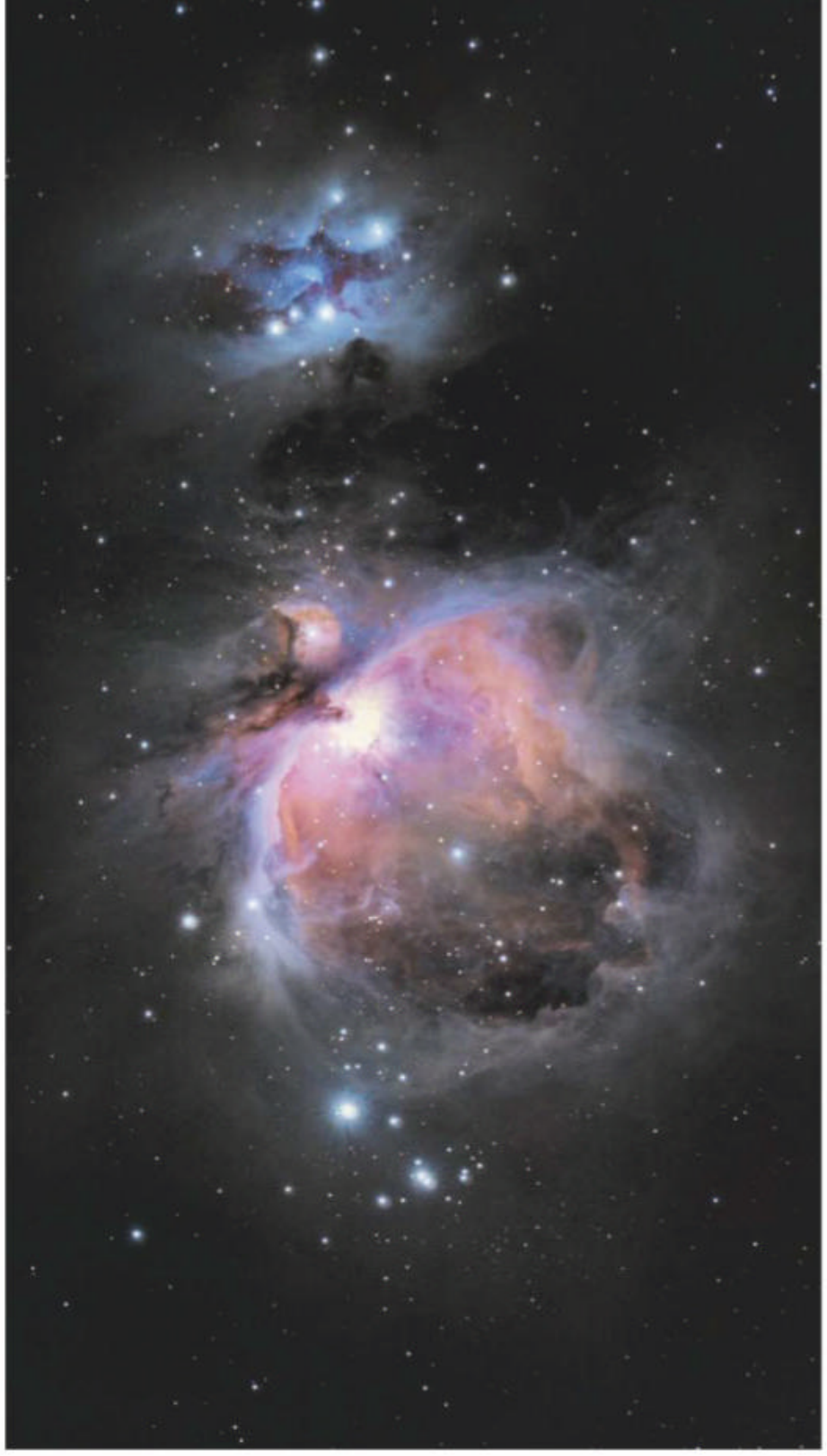
Equipment: Canon Powershot SX50 digital camera, iOptron SkyTracker mount
Exposure: ISO 800 f/8, 1/1250"–15"
Software: Affinity Photo

The Flame and Horsehead Nebulae ▷

Jack Sharp, Norfolk, 16 November 2018

Jack says: "This is part of an eight-panel mosaic that will eventually include Orion's Belt down to M42 (if the clouds ever go away). I was pleased with the outcome of this panel so I decided to share it despite needing more data to complete the whole mosaic."

Equipment: ZWO ASI1600MC Pro colour camera, Altair Starwave 70 EDQ-R imaging refractor, Sky-Watcher AZ-EQ6 GT Pro mount **Exposure:** 48x300"
Software: PixInsight, Photoshop



◁ The Orion Nebula

Christopher Garman, Skelmersdale, 17 November 2018

Christopher says: "M42 was my first ever astrophoto, which I took in 2017, so in 2018 I wanted to sink some more time into it and use the knowledge I have gained. I also have a better telescope now and wanted to see what it could do."

Equipment: Nikon D750 DSLR camera, Explore Scientific ED102 triplet apo refractor, Sky-Watcher HEQ5 Pro mount
Exposure: 135x2' lights, 10x2' darks, 200x1/4000" bias
Software: PixInsight, Photoshop

The lunar eclipse begins ▷

Dmitry Ardashev, Moscow, Russia, 21 January 2019

Dmitry says: "It was cloudy and I knew I wouldn't have much time. As it started I took a series of shots with different exposures to capture the Moon, clouds and trees. I was afraid the pictures wouldn't be sharp enough, but it seems one of the shots was successful."

Equipment: Canon EOS 200D DSLR camera, Canon EF 28–200mm lens
Exposure: ISO 800 f/7.1, 1/13"
Software: Lightroom, FastStone Image Viewer

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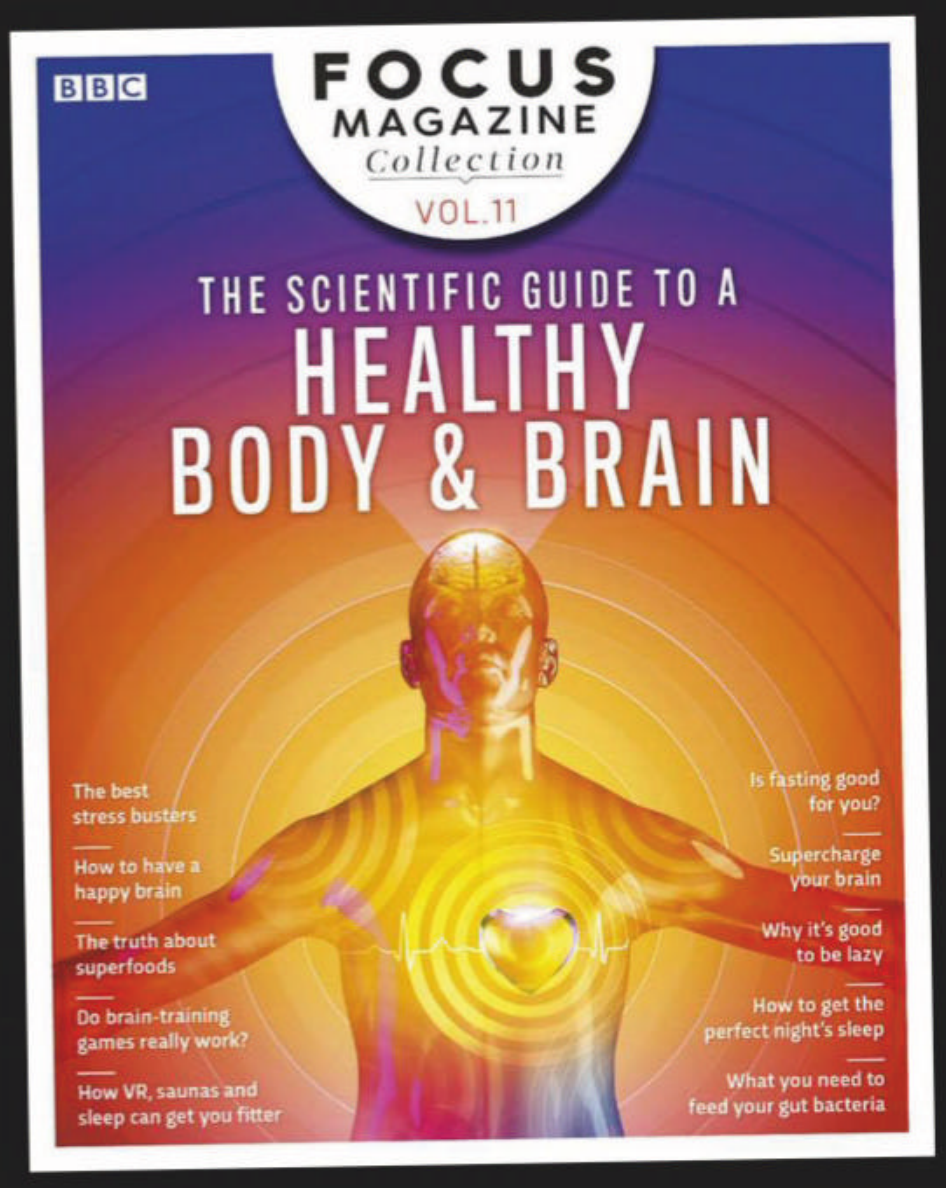

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86
Travel light with the Zenithstar 61, the affordable and highly portable new scope from William Optics

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HOW WE RATE

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★★★★★ Outstanding ★★★★★ Very good
★★★★★ Good ★★★★★ Average ★★★★★ Poor/avoid

William Optics Zenithstar 61 apo refractor

Light, compact and sturdy, this scope makes the perfect travelling companion

WORDS: PETE LAWRENCE

VITAL STATS

- **Price** £415
- **Optics** FPL-53 air-spaced doublet, fully multi-coated
- **Aperture** 61mm
- **Focal length** 360mm, f/5.9
- **Focuser** 1:10 dual speed rack and pinion
- **Dew shield** Retractable
- **Mounting** Rotatable L-bracket
- **Extras** Bahtinov mask, thermometer
- **Weight** 1.7kg
- **Supplier** Widescreen Centre
- **Tel** 01353 776199
- **www.** widescreen-centre.co.uk

ALL PICTURES: WWW.THESECRETSTUDIO.NET

Dark skies can be something of a luxury if you live in an urban environment and you may find you have to travel to escape the light pollution and see the cosmos at its best. Or perhaps you're lucky enough to holiday somewhere where the skies are dark and the opportunity for looking up is irresistible. Either way, dragging a large, cumbersome telescope with you soon loses its appeal and this is where portable scopes like the William Optics Zenithstar 61 (ZS61) come into their own.

In terms of portability it's difficult to imagine how you could improve on this 61mm aperture refractor's design. In its most compact form it measures just 23cm long by 14cm wide. It's also pretty light at 1.7kg but retains a solid, well-built feel. The front of the instrument has a retractable dew shield that extends the overall length by a further 7cm.

For such a small scope we were really impressed with the attention to detail. The ZS61 uses a dual-speed rack-and-pinion focuser which we found smooth and precise to use. An adjustment thumbscrew allows you to alter its feel to suit your own preference. One of the focuser dials has a rotary thermometer built in so you can even record the temperature while observing.

Sharp and bright

At the front end there is a colour coordinated lens cap that fits on the dew shield. This contains a focus aid accessed by unscrewing a metal end-plate. Inside is a Bahtinov mask, an optical device created from a number of inclined parallel slots through which starlight can pass. The slots produce a pattern that aids accurate focusing.

The front objective is an air-spaced doublet formed from low dispersion FPL-53 ED glass. This produces lovely colour-corrected views. We were hard pressed to see any rogue colour fringing at all on bright stars or the Moon. The scope's 61mm aperture and natural focal length of 360mm gives the ZS61 a focal ratio of f/5.9, which is neither particularly fast nor slow.

It's important to be realistic with the ZS61's aperture. It produces lovely views of larger deep-sky ▸

See an interactive 360° model of this scope at www.skyatnightmagazine.com/WOZeni61

Impressive optics

The ZS61 has a 61mm objective lens made from two FPL-53 extra-low-dispersion (ED) glass elements. FPL indicates that the material contains fluorite (or a synthetic form of fluorite) and lead (chemical symbol Pb). The 'L' means that the material is low dispersion. This creates an optical material that has very low chromatic aberration, ideally suited for colour-corrected telescope optics. The two lens elements are air spaced to form a doublet lens. Each element is designed to bring the two ends of the visible spectrum to a convergent focus. All this adds up to a lens with virtually no unwanted colour fringing.

Further refinement is provided by super-multi coatings (SMCs) to reduce unwanted refraction and reflections. Inside the optical tube, circular baffles are fitted as field stops, limiting the field of view to just that provided by the objective lens. This helps reduce unwanted effects such as off-axis light reflected from inside the optical tube, and further increases the quality and contrast of the view.

Optical tube

The ZS61's optical tube is made to a high standard and attractively finished in white. It has highlighted colour accents around the base of the dew shield, the lens caps and Bahtinov mask, and the slow focus knob. Gold, blue and red variations are available.

Retractable dew shield

A dew shield does exactly what its name suggests: shield the objective lens from moisture build up. In the case of the ZS61, the front dew shield extends by 7cm from its retracted travel position. The motion is smooth and the shield holds position when pointed at high inclination angles.

Focuser

The 2-inch, 1:10 dual-speed focuser is fitted with a triple-screw compression ring. A 1.25-inch adaptor is also included as standard. Four hex screws allow the focuser tension to be adjusted, with a larger thumb screw for quick adjustment. The rack-and-pinion focuser provides 70mm of travel and has a millimetre scale printed on the draw tube.

FIRST LIGHT

KIT TO ADD

1. William Optics Flat61 Flattener for ZS61

2. William Optics 2-inch Rotolock for ZS61 / GT71

3. William Optics soft carry case for ZS61

▸ objects and the Moon but it can't break the laws of physics. Such views will typically be low power and of limited resolution. If you're after detailed views of the planets, are into hunting small lunar features or splitting tight double stars, this isn't the scope for you. But if you want an ultra-portable instrument that can provide good contrast, colour-corrected views of extended objects, it's perfect.

Through the eyepiece stars appeared sharp and bright. We loved the views it gave of large open clusters such as the Pleiades and the Beehive Cluster. The Double Cluster looked amazing too, like spilt sugar on a dark velvet background. We also loved the enhanced overview of the Moon this scope gave. The contrast was excellent, with dark shadows looking inky black against the bright lunar highlands.

One area likely to attract interest is the ZS61's use for astrophotography. Carrying an ultra-portable telescope and camera provides a fantastic opportunity to make the most of dark-sky locations. Here the Bahtinov focus mask and smooth, responsive focuser work really well together. Using a Live View-enabled DSLR, diffraction patterns produced by the mask were relatively easy to see and we were able to reach perfect focus with ease.

One slight disappointment is a distortion across the imaging frame. Stars appear sharp at the centre of the field but become progressively stretched out towards the frame edge and corners. This can be addressed by using a matching field flattener and for the ZS61 the William Optics Flat61 is the device to go for. This optional extra is a must if your objective is astrophotography and will set you back around £149.

If portable astronomy is important to you, the William Optics Zenithstar 61 is a very tempting and reasonably priced option. Coupled with the optional field flattener and one of the many portable battery-driven equatorial mounts currently available, all you need to do is hunt out those dark skies.

VERDICT

Build and design	★★★★★
Ease of use	★★★★★
Features	★★★★½
Imaging quality	★★★★½
Optics	★★★★½
OVERALL	★★★★½

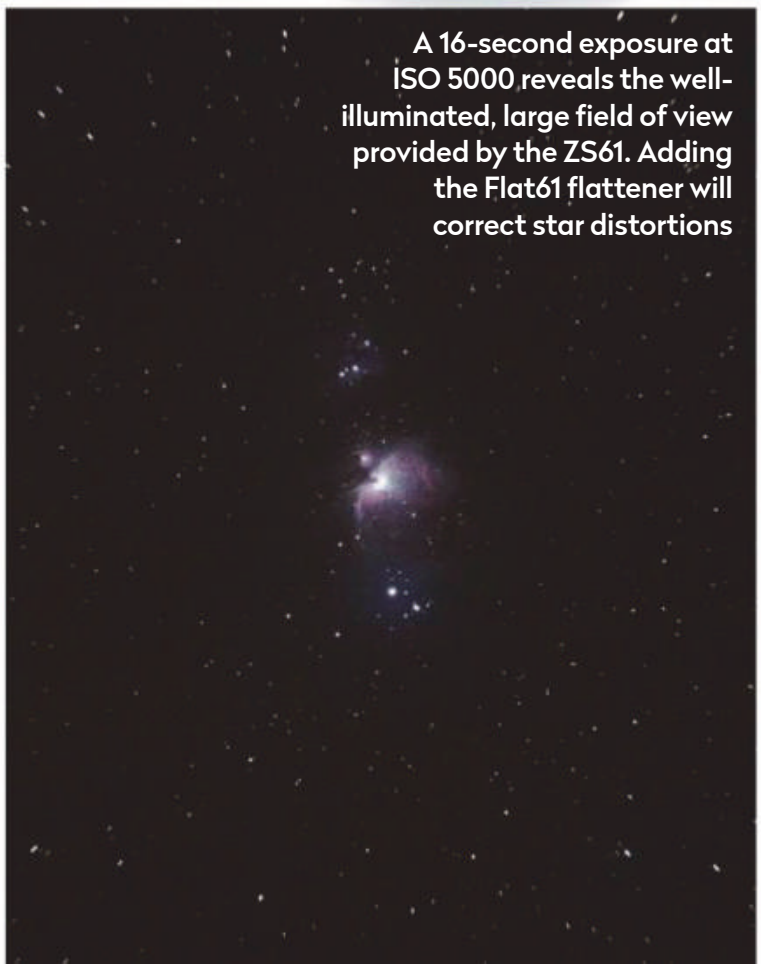
WWW.THESECRETSTUDIO.NET X 2, PETE LAWRENCE

L-type bracket

The ZS61's optical tube has a recessed channel around which is a ring clamp connected to an L-type bracket. Scope orientation is adjusted by loosening the clamp then locking it with a thumb screw. The L-shaped foot is Vixen compatible and has two ¼-inch and one ⅜-inch threaded holes on its underside.

Bahtinov mask

The ZS61's lens cap has a threaded top that unscrews to reveal a Bahtinov mask – an optical arrangement of slits that produce diffraction spikes when starlight passes through them. When the spikes appear sharpest and pass through the same central crossing point, the scope is focused. Once focused, the collar containing the mask is removed.



A 16-second exposure at ISO 5000 reveals the well-illuminated, large field of view provided by the ZS61. Adding the Flat61 flattener will correct star distortions

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Altair Ultraflat eyepieces

An impressive new range, but can they really eliminate field curvature?

WORDS: STEVE RICHARDS

VITAL STATS

- **Price** £65, £89, £99, £135, £169
- **Focal length** 10mm, 15mm, 18mm, 24mm, 30mm
- **Apparent field of view** 60°, 65°, 65°, 65°, 70°
- **Eye relief** 16mm, 20mm, 29mm, 22mm
- **Optical elements** 4, 8, 8, 8, 9
- **Barrel size** 1.25-inch (10–24mm eyepieces), 2-inch (30mm eyepiece)
- **Weight** 109g, 172g, 245g, 431g, 676g
- **Extras** Lens caps, microfibre cloth
- **Supplier** Altair Astro
- **Tel** 01263 731505
- **www.**altairastro.com

ALL PICTURES: WWW.THESECRETSTUDIO.NET

Altair's new Ultraflat eyepiece collection has been specifically designed to help correct field curvature, an aberration that results in stars towards the edges of the field of view taking on an elongated shape. But while we were generally impressed with the range, the name 'Ultraflat' may be overstating the case.

The eyepieces are very nicely presented in a most attractive satin green anodised finish with a bright stainless steel barrel and contrasting black rubber grip and eyecup. The focal length of each is printed in white on the green, giving plenty of contrast when viewed using a red light torch. Overall they have a quality feel to them.

The collection comprises oculars with focal lengths of 10mm, 15mm, 18mm, 24mm and 30mm, making them suitable for a wide range of celestial observations although, surprisingly for a collection of this type, the apparent field of view (AFOV) is not common throughout the range. The 15mm, 18mm and 24mm eyepieces each have an AFOV of 65°, while the 10mm and 30mm have AFOVs of 60° and 70° respectively.

Focus and fit

All of the eyepieces have 1.25-inch barrel diameters except for the 30mm, which demands a 2-inch barrel to achieve its 70° apparent field of view. This is because the field stop of a 1.25-inch barrel would be a limiting factor here. To make use of the whole collection you may therefore require an eyepiece adaptor to accommodate both sizes. The eyepieces all include filter threads in their respective sizes.

We tested the eyepieces to see if they were parfocal – that is, that the focus point stays exactly the same while you zoom the lens – as this can be a very useful attribute when swapping from one eyepiece to another to minimise focus adjustments. The 18mm and 15mm versions were fully parfocal, with the 24mm and 10mm requiring the smallest of adjustments with less than a millimetre of focus travel to cover them all. The 30mm version required an extra 11mm of outwards focus travel as we would ▸

Ultraflat or not?

Nearly all telescopes suffer from field curvature to some extent, resulting in only the stars at the very centre of the field of view – those that are 'on-axis' – being in perfect focus. The further off-axis you look, the greater the amount of distortion in the star shapes. Although field curvature is a big issue for astrophotographers, it isn't for observers as eyepieces and the human eye and brain tend to compensate.

The Altair Ultraflat eyepieces aim to form distortion-free images right up to the field edge, even in very fast focal ratio telescopes.

We tested the effect of off-axis distortion through a high-quality refractor by observing a bright star centred in each eyepiece, turning off the mount tracking and noting the point at which distortion became noticeable as the star traversed the field of view.

Generally, while the Ultraflat eyepieces produced excellent views, we were not able to observe any marked effect on field flatness in comparison with other eyepieces that we've used.

See an interactive 360° model of these eyepieces at www.skyatnightmagazine.com/AltairUltra

Fold-up rubber eye cup

It is important to shield the observer's eye from stray light and to allow for steady and repeatable eye placement when observing. The rubber eye cups on these eyepieces do this very well and can be folded down for spectacle wearers.

Rubber grip

Outside in the cold and dark it is all too easy for a prized eyepiece to slip from your grasp with potentially disastrous consequences. Manufacturers go to some lengths to make their eyepiece bodies ergonomically friendly to help prevent such mishaps. The textured rubber grip on the Ultraflats is very effective.

Safety kerfs

Although not unique to this range of eyepieces, the lens barrels of the Ultraflats have been machined with multiple grooves every 2mm. These are known as 'safety kerfs' and they provide an excellent grip for the compression rings found on most modern eyepiece holders, while obviating the risk of snagging.

FIRST LIGHT

KIT TO ADD

1. Altair Premium CLS filter

2. Altair DewZapper 2-inch premium dew heater

3. Altair 2-inch premium positive lock diagonal

Multi-coating

In telescopes and eyepieces it is important to minimise the light reflected from the lens surfaces so that maximum light passes through to the observer's retina. Multi-coatings that reduce reflections have been applied well on these Altair eyepieces.

ALL PICTURES: WWW.THESECRETSTUDIO.NET

▸ have expected because its 2-inch barrel didn't, of course, require the 1.25-inch adaptor which has a depth of 11mm.

Colour correction was generally good, although the 10mm eyepiece displayed a little false colour even on axis. The field stop in all of the eyepieces was sharply defined and, with the rubber eyecups folded down, could be seen in all of the eyepieces when wearing glasses.

Taking them on tour

We put the eyepieces to the test by observing a range of objects using our own William Optics 2-inch Dielectric Diagonal attached to both our observatory-mounted William Optics FLT 98 apo refractor and our grab-and-go Megrez 72FD scope.

The review period coincided with comet 46P/Wirtanen being well placed and a break in the cloud cover on the night of 13 December, coinciding with the comet traversing Taurus, was too good an opportunity to miss. Wirtanen proved to be a great object for observing at low power using the 30mm eyepiece in our 4-inch FLT 98.

Three days later, at the crack of dawn, with the 10mm eyepiece in our Megrez 72FD we observed the brilliant planet Venus enjoying a really distinct crescent set against a delightful blue backdrop. The Pleiades star cluster was beautifully displayed in the 24mm mounted in our FLT 98, and a small slew to the east on 16 December brought us back onto the comet for another enjoyable look.

At around this time we also enjoyed some fantastic views of the Moon using the 10mm and 15mm eyepieces and caught tantalising glimpses of Mare Humboldtianum on the northeastern limb. The 18mm eyepiece produced a lovely framing of M42, the Orion Nebula, and the Running Man Nebula. We chose Betelgeuse as our star test subject and found that each eyepiece produced well-formed stars out to over 85 per cent of the field of view in our FLT 98 refractor, which is very respectable but not what we'd call 'ultra' flat.

We liked this collection of eyepieces as they produced excellent views, although we didn't particularly feel that they had a marked effect on field flatness. However, they are still a good range and we would recommend them to both beginner and intermediate observers.

1.25-inch and 2-inch barrels

Modern eyepieces have barrels in two sizes. Most popular is 1.25-inch, but the needs of very long focal length oculars or those with very wide fields of view dictate a larger diameter. All the eyepieces in this collection are 1.25-inch push-fit, with the exception of the 30mm eyepiece with its 2-inch barrel.

VERDICT

Build and design	★★★★½
Ease of use	★★★★½
Extras	★★★★½
Eye relief	★★★★½
Optics	★★★★½
OVERALL	★★★★½

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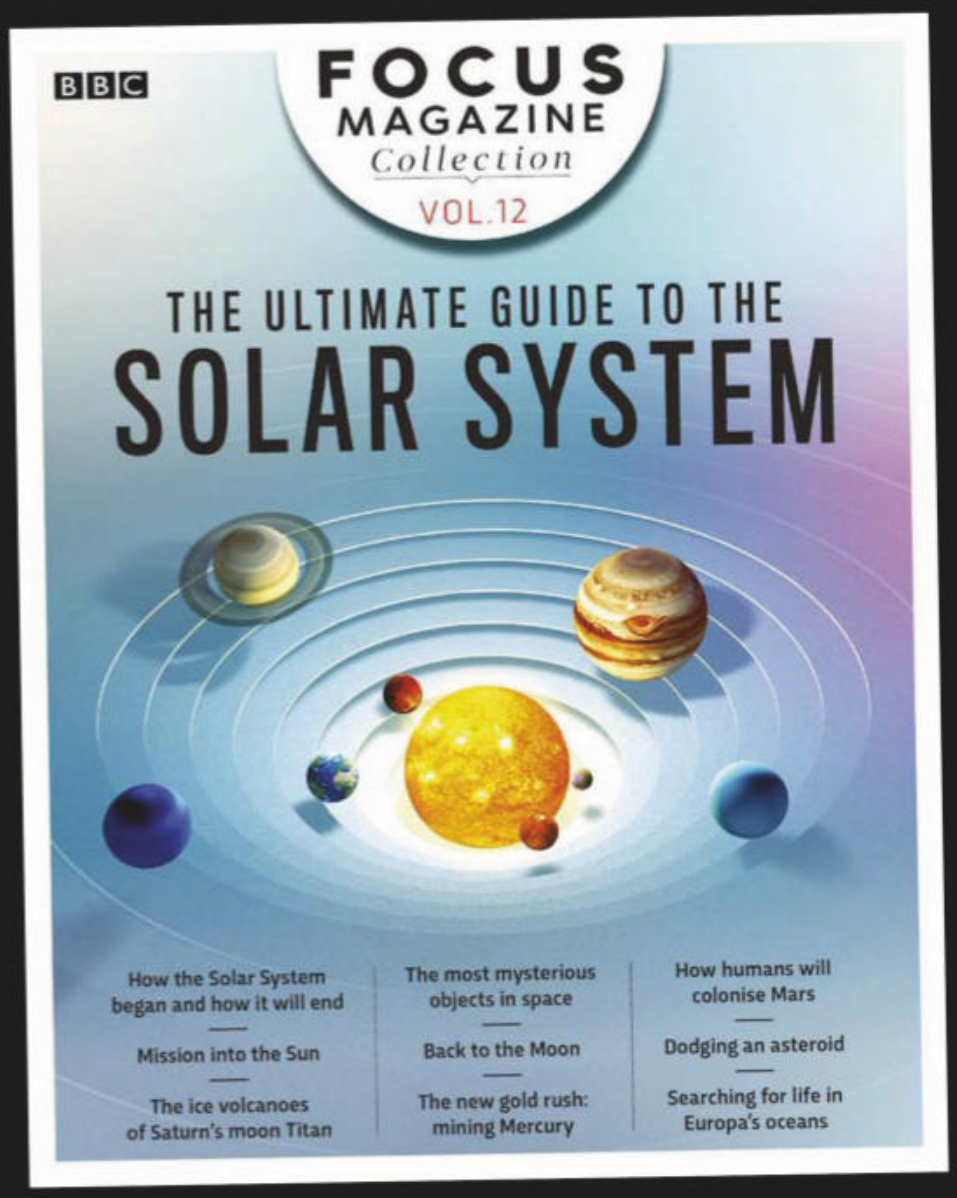

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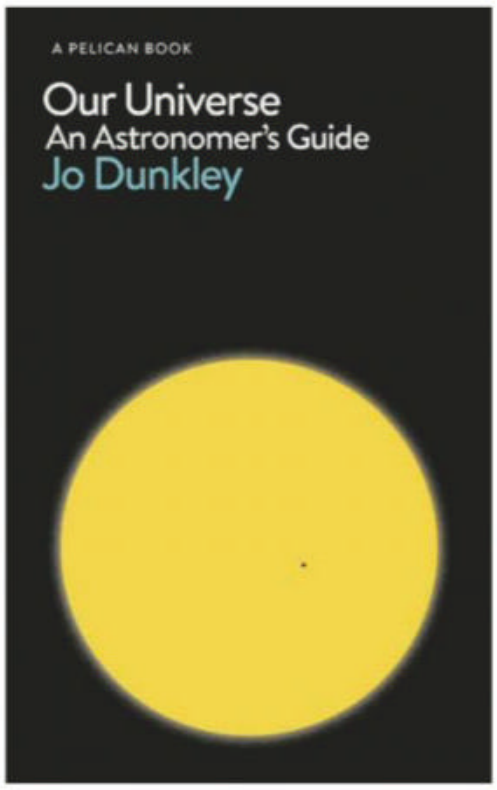
BOOKS



Our Universe: An Astronomer's Guide

Jo Dunkley
Pelican
£20 ● HB

A professional astronomer trying to explain the Universe to a lay audience – isn't that bound to fail? Well, not if her name is Jo Dunkley. In her introduction to everything cosmic, Dunkley takes her readers on a grand tour of space and time, from our nearest planetary neighbours to the edge of the observable Universe. *Our Universe* is nothing less than a comprehensive crash course in astronomy.

The book follows a very traditional and well-trodden path, starting with an overview of the history of astronomy and a description of our Solar System – the familiar "here and now", as the author writes. Stellar evolution is next, followed by a chapter that focuses on galaxies, clusters and the mystery of dark matter. The birth, evolution and future of the Universe are discussed in the final chapters.

Dunkley's explanations are always extremely clear, her metaphors are to the point and her arguments easy to follow. Throughout the book she highlights numerous historical and recent scientific results in astrophysics and cosmology, with a welcome emphasis wherever possible on contributions from female astronomers like Williamina Fleming and Vera Rubin.

Since Dunkley is a former scientist of NASA's WMAP satellite and a team member of various cosmological observatories, you might expect her cosmological chapters to be a bit hard to swallow, but here too the book is very accessible to every interested reader. It's also good to hear a cosmologist admit how little we really know for sure about the origin of the Universe.

A minor complaint might be that present-day planetary science receives relatively little attention in the book (comets aren't mentioned even once!). Also, *Our Universe* is more textbook than science journalism: apart from a number of well-known historical anecdotes, there's not much human interest and story-telling.

▲ **Dunkley's is a crystal-clear and accessible tour of space and time**

BRUCE ROLFF/ALAMY STOCK PHOTO

For most *BBC Sky at Night Magazine* readers, much of the content of this book may be familiar. But if you feel like refreshing your background knowledge, or if you're looking for a birthday present for your curious niece or nephew, this little gem certainly won't disappoint.

★★★★☆

***Govert Schilling** is an astronomy writer and author of the book* Ripples in Spacetime

Interview with the author Jo Dunkley

What have been the most important developments in astronomy over the past 100 years?

Technologically it would be the ability to detect non-visible light from space, including radio waves and X-rays, and the invention of CCDs to take better digital images. Scientific highlights are the discovery of galaxies beyond the Milky Way, that stars are mostly balls of hydrogen and helium gas, that much of the matter in space is invisible, and that our Universe had a beginning. A major recent development has been the discovery of a wealth of diverse exoplanets.

Who do you think are astronomy's biggest unsung heroes?

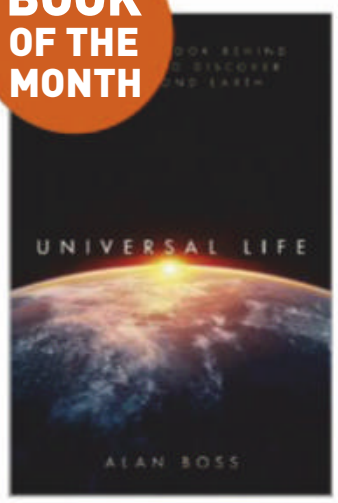
For me, it's the women of the story. In 1908, Henrietta Swan Leavitt discovered that a type of pulsating star could be used to measure vast distances, the key to finding out that our Galaxy is one of many. In the 1920s, Cecilia Payne-Gaposchkin worked out what the Sun and other stars are made of. And in the 1970s, Vera Rubin established that most of the matter in the Universe is completely invisible. All enormously important, but none of them got the credit they deserved.

What mysteries do you want solved?

I want to know if there is life elsewhere. I want to know why the Universe started growing at the Big Bang, what dark matter is and whether Einstein got the law of gravity exactly right. I am also fascinated to find out what major paradigm shift about our Universe might be waiting around the corner.

***Jo Dunkley** is a professor of physics and astrophysical sciences at Princeton University*

BOOK OF THE MONTH



Universal Life

Alan Boss
Oxford University Press
£16.99 ● HB

After nine years of looking for planets beyond our Solar System, in October 2018 the Kepler Space Telescope ran out of fuel and was retired by NASA. But, how did the mission go from a concept to discovering over 2,600 exoplanets?

In 17 easy-to-digest chapters we are treated to a behind-the-scenes look at the incredible 20-year journey Kepler endured to reach launch-ready status; how it survived several rejections, running out of money and had to follow the failed launch of NASA's $273 million Orbiting Carbon Observatory.

Thankfully, on 6 March 2009 Kepler did finally hitch a ride on a Delta II rocket with the goal of finding the first Earth-like habitable planet. It took a while, but in 2011 the team were rewarded with the discovery of Kepler-22b – the first known transiting exoplanet around a Sun-like star.

Through personal anecdotes it becomes clear that astronomers often dedicate entire careers to space missions, so by the time crucial components start to fail aboard Kepler, the reader is heavily invested in its survival.

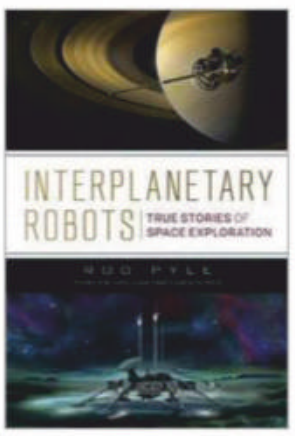
Kepler aside, Boss also provides insight into how a multitude of missions have progressed over the last decade, from his unique perspective overseeing aspects of NASA's 2010 decadal survey of the science community. This was one of the most interesting elements of the entire book.

If you've ever wanted to understand why space missions take decades to be realised, with some science highlights scattered in between, then give Boss's latest book a go. It's a page-turner that is worthy of multiple rereads.

★★★★★

***Amber Hornsby** is a postgraduate researcher based in Cardiff University's Astronomy Instrumentation Group*

Interplanetary Robots:
True Stories of Space Exploration



Rod Pyle
Prometheus Books
£14.99 ● PB

Pyle has long been a fan of NASA's Jet Propulsion Laboratory. He tells how, as a college student, he used local knowledge to join the press covering JPL's Viking 1 touchdown onto Mars. Much later he snagged a job at JPL, the source of much of this book's inside information.

This is an irreverent history that includes 'flash forward' diversions to future mission concepts, such as a submarine to search Titan's hydrocarbon lakes, a clockwork rover to roam Venus and probes to neighbouring stars accelerated by Earth-based lasers. Pyle also looks at exploration paths *not* taken, like a crewed fly-by of Venus planned using Apollo hardware and a proposed 1950s nuclear strike on the Moon.

Such an explosive course wouldn't have been far removed from the first exploratory probes, designed either to smash into the lunar surface or speed past while taking snaps. But Cold War competition forced their rapid evolution into precisely-controlled soft landers and orbiters. Today, all eight planets, plus Pluto, have been surveyed by robots and there's a nuclear-powered car trundling around Mars.

Pyle doesn't pretend to cover all missions. To European eyes he sticks too close to the traditional US–Russia Space Race narrative. Missions shepherded by other US entities – such as the Applied Physics Laboratory overseeing New Horizons – receive less coverage than JPL spacecraft. Pyle notes how in one JPL control room 'The Center of the Universe' is etched cheekily on the floor. It's certainly the centre of this book; it's a bit of a shame that it didn't adopt a wider perspective.

★★★★☆

***Sean Blair** writes for the European Space Agency website*

Cosmic Impact:
Understanding the Threat to Earth from Asteroids and Comets

Andrew May
Icon Books
£8.99 ● PB

If you are curious about Near-Earth Objects (NEOs), what they are, the threats they pose and how these threats may be overcome, *Cosmic Impact* is the book for you. This new work from Andrew May is bursting with information. May weaves history, science and religion to provide a wide-ranging narrative that includes the demise of the dinosaurs, the behaviour of NEOs in space, how they can be tracked and how comets have been perceived by humankind throughout history. Who could forget the Heaven's Gate cult in California, for example, and their belief in a spacecraft following Comet Hale-Bopp?

Those of us hoping for a Hollywood film solution to tackle NEOs that threaten our existence will be disappointed, but May's explanation of how to deflect these potentially perilous visitors is very well explained. *Cosmic Impact* is littered with references and examples from science fiction and science fact and there is a comprehensive reading list provided at the end of the book, which I am almost certain every reader will want to go on and explore.

The text is superb but it seems a shame that May did not make use of more diagrams and photos to illustrate his descriptions and examples. That aside, *Cosmic Impact* makes for worthy reading. It is informative and clear, and May manages to encapsulate everything you need to know about the potential risk to our planet and species posed by these fascinating Solar System voyagers.

★★★★☆

***Katrin Raynor-Evans** is a fellow of the Royal Astronomical Society and the librarian at Cardiff Astronomical Society*

Elizabeth Pearson rounds up the latest astronomical accessories

GEAR

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2 Dust Ex air blower

Price £12.99 • **Supplier** F1 Telescopes
Tel 0845 260 2622 • **www.f1telescopes.com**
Expel dust from sensitive optical and electronic equipment without physical contact using a powerful blast of air from the Dust Ex.

3 Eurohike roll top table

Price £80 • **Supplier** Millets
Tel 0161 393 7060 • **www.millets.co.uk**
This foldable table allows you to keep your equipment within easy reach, then packs up for transportation, making it a great option for when you are doing astronomy away from home. It measures 109x12x21cm when folded and weighs 5kg.

4 Bresser 5-in-1 weather centre

Price £127 • **Supplier** Bresser UK
Tel 01342 837098 • **www.bresseruk.com**
Work out the ideal time to observe using this weather station. Comes with an outdoor sensor that measures wind speed and direction, humidity, temperature and precipitation. The display can show both current and past weather measurements.

5 CCD Guide 2019

Price €29 • **Supplier** Astronomischer Arbeitskreis Salzkammergut • **www.ccdguide.com**
Plan your next big astrophotography project with the help of this DVD. This 2019 edition contains the new ObjectTracker which lets you know whether an object can be photographed at your location and what time of night it will be best placed for capture. Comes with over 5,000 reference images.

6 Vixen LED Compass

Price £14.95 • **Supplier** Tring Astro
Tel 01442 822997 • **www.tringastro.co.uk**
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Shaoni Bhattacharya interviews leading experts in space science

WHAT I REALLY WANT TO KNOW IS...

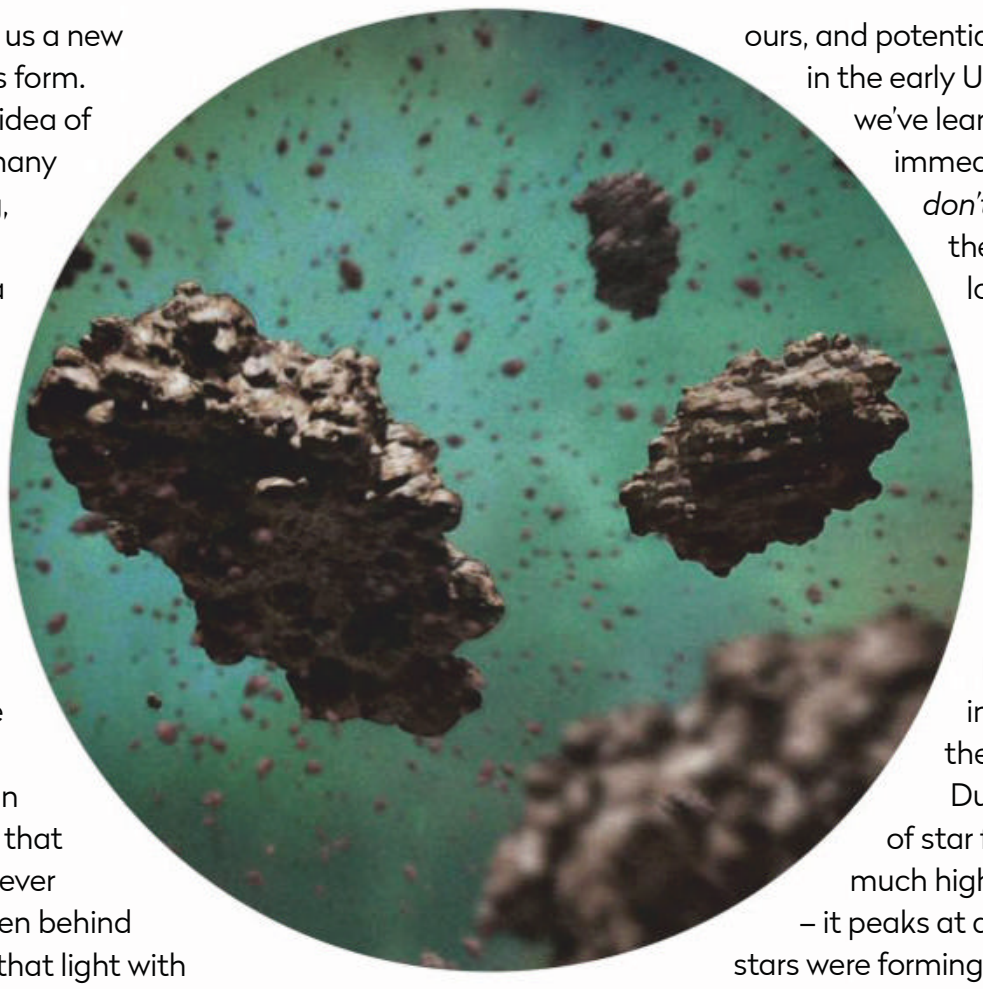
What can cosmic dust tell us?

Faintly glowing dust grains are everywhere in space, says **Professor Haley Gomez**, but only now are we uncovering this 'hidden Universe'

Cosmic dust gives us a new view of how stars form. It can give us an idea of when and how many stars are forming, how much gas a galaxy has and how enriched a galaxy may be. The more dust, the more material, which means more iron, silicon, carbon and oxygen-rich gas – all the things we know are important for life.

'Cosmic dust' is an umbrella term for small grains of rock in space. Most of it is smoke particle-sized, although it can be as large as an Earth-like planet. And there's a huge amount of it in and between galaxies. We know that around half of all starlight that's ever shone since the Big Bang is hidden behind cosmic grains. And we can't see that light with traditional telescopes like Hubble.

But we can measure the glow of the dust grains using 'submillimetre' light. In 2009, the Herschel Space Observatory was launched and this gave us the first 'Hubble equivalent' to see the 'hidden Universe'. Our COSMICDUST project is mostly exploiting data taken by Herschel, as well as from NASA's infrared telescope, Spitzer.



▲ **An artist's impression of cosmic dust, the grains responsible for obscuring half of all starlight since the Big Bang**

MARK GARLICK/SCIENCE PHOTO LIBRARY

Delving into dusty galaxies

Imagine a bunch of stars in a gas cloud with lots of dust. That dust acts like smog, trapping starlight and heating up. As the dust is very cold at -250° Celsius, it only glows with a very, very infrared light. The stars are like a fire, heating up ash. With the visible light from the stars and the submillimetre light from the dust, together you have the total energy.

We are trying to capture that missing starlight by searching for the glow from the ashes. There are some galaxies that you literally cannot see with Hubble, but with Herschel you can see them glowing brightly. We've so far investigated about 300,000 dusty galaxies, as well as dust in the Milky Way.

If we see dust in a galaxy, that can tell us it has the raw materials to create planets and solar systems like ours, and potentially life itself. By observing dust in the early Universe just after the Big Bang, we've learned that planets can form immediately after the first stars. If we *don't* see dust then we know that the timescale may be much longer. That gives you a handle on when planets, and life, might have formed.

Galaxies in our backyard with lots of dust are very gas-rich, which means they are very young. If we use what we know about dust in our local galaxies we can infer how much gas is in galaxies in the earliest phases of the Universe.

Dust also tells us that the amount of star formation in the Universe is much higher than we ever imagined – it peaks at about 10 billion years ago, when stars were forming at a crazy rate. Our Galaxy today is so much calmer: about one star forms in a year; back then there were 10,000 per year.

The data implies that the Universe was dustier then. We don't know why. That's something we are trying to figure out: what is making the Universe cleaner?

What I work on mostly at the moment is where all this stuff comes from. When I did my PhD, I was told that dust forms in stars like the Sun, in stellar winds before they die. But, confusingly, we see dust everywhere. It can't be from stars like the Sun – there's not enough of them, they don't form enough dust and it would take too long to evolve to that stage (at least 10 billion years for the Sun).

Our theory was that maybe dust forms in more explosive environments. Everyone said "no way – supernovae blow up, little bits of soot would be melted back into gas straight away". But from our observations of supernovae from our own Galaxy and nearby, pretty much everywhere you look that stars have exploded, there is dust.

If by the end of the project we could say, "Yes, this is where dust is formed," the textbooks will need rewriting. They currently don't really include supernovae as a source of dust. That would be nice – but we could be wrong of course!

Professor Haley Gomez is Professor of Astrophysics at Cardiff University. She is also the lead on the European Research Council-funded project, COSMICDUST

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THE SOUTHERN HEMISPHERE

With Glenn Dawes

Spectacular multi-starred Gamma Velorum sails over the Southern sky this month

When to use this chart

1 March, 24:00 AEDT (13:00 UT)
15 March, 24:00 AEDT (13:00 UT)
31 March, 23:00 AEDT (12:00 UT)

The chart accurately matches the sky on the dates and times shown for Sydney, Australia. The sky is different at other times as the stars crossing it set four minutes earlier each night.

MARCH HIGHLIGHTS

The Southern Hemisphere has only a handful of exclusive annual meteor showers. The Gamma Normids are an example, expected to be active from 25 February to 28 March. They are normally bright, showing some colour, occasionally yellow or orange, with some trains. Best observed after midnight, at peak activity (14 March) the first quarter Moon ensures the morning will be dark. This also allows the radiant in the constellation of Norma, the Set Square, time to gain altitude.

STARS AND CONSTELLATIONS

Gamma Velorum is located in the southern constellation of Vela, the Sail. A brilliant multiple star, Gamma's brightest member consists of a binary pair of supergiants, one being a Wolf-Rayet type. These young, intensely hot stars lose mass at a prodigious rate through their stellar winds. In fact, this star started its life around 35 solar masses and is now down to nine. It is believed to be one of a handful of stars within 1,000 lightyears of Earth that could be the Milky Way's next supernova!

THE PLANETS

March marks the end of Uranus as an evening planet; it will only be visible low in the western twilight sky. Mars isn't far behind, departing around 21:00. Jupiter has moved into the evening, rising around 23:00 midmonth. The early morning sees the arrival of Saturn, followed by Venus around 03:00. Early in the month Mercury and Neptune return to the morning, rising before dawn by month's end. On 31 March the most inner planet has closed to only 1.3° from the most outer planet.

DEEP-SKY OBJECTS

This month, take a trip to the realm of Canis Major, the Greater Dog. From Sirius move 3.7° northeast to the close double star, Mu (μ) Canis Majoris (RA 6h 56.1m, Dec. -14° 03'). It has a yellow primary with a white companion, mag. +4.7 and +9.7 respectively, a tight 3 arcseconds apart.

Continue this star hop a further 5.5° east-southeast, to reveal the open star cluster NGC 2360 (RA 7h 17.7m, Dec. -15° 38'). About 12 arcminutes in diameter, its overall brightness is around mag. +7. It has a handful of 10th-magnitude stars, with the majority of its 80-ish members at around 11th–13th magnitude. What makes it most interesting are the numerous clumps and lines of stars, with an attractively placed bright (mag. +5.4) field star, 20 arcminutes to the west – brilliant in low power!

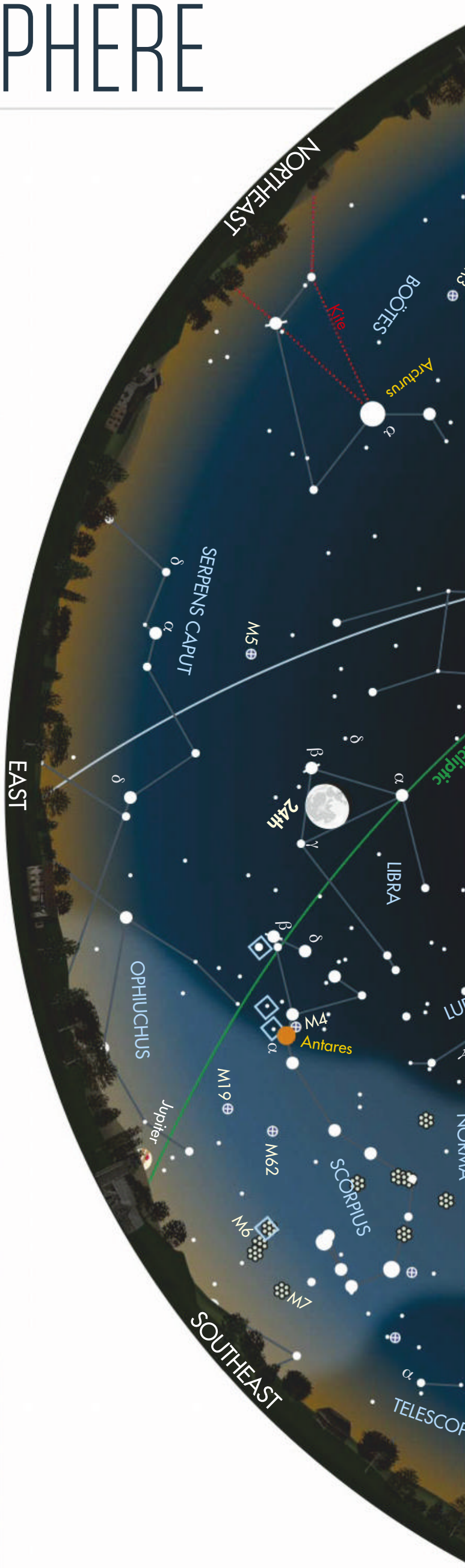

Chart key

- GALAXY
- OPEN CLUSTER
- GLOBULAR CLUSTER
- PLANETARY NEBULA
- DIFFUSE NEBULOSITY
- DOUBLE STAR
- VARIABLE STAR
- COMET TRACK
- ASTEROID TRACK
- METEOR RADIANT
- QUASAR
- PLANET

STAR BRIGHTNESS:
- MAG. 0 & BRIGHTER
- MAG. +1
- MAG. +2
- MAG. +3
- MAG. +4 & FAINTER

CHART: PETE LAWRENCE


NORTH
NORTHWEST
WEST
SOUTHWEST
SOUTH
URSA MAJOR
CANES VENATICI
LYNX
LEO MINOR
GEMINI
Castor
Pollux
COMA BERENICES
CANCER
LEO
Sickle
18th
15th
M44
M35
Regulus
M65/66
M64
M60
M87
M86
M49
21st
VIRGO
Procyon
CANIS MINOR
Betelgeuse
ORION
Celestial Equator
SEXTANS
Rosette Nebula
Alphard
CRATER
CORVUS
M104
Spica
Ghost of Jupiter
M48
M47
NGC 2360
Winter Triangle
M50
MONOCEROS
M78
ANTLIA
HYDRA
M68
M83
PYXIS
PUPPIS
Sirius
M41
CANIS MAJOR
M42
Rigel
VELA
Eta Carina Nebula
Omega Cen
CENTAURUS
CRUX
Jewel Box
Acrux
False Cross
NGC 2516
CARINA
Canopus
COLUMBA
LEPUS
ERIDANUS
Rigel Kent
Hadar
MUSCA
CIRCINUS
Gamma Normids Peak 14 March
VOLANS
PICTOR
LMC
CAELUM
TRIANGULUM AUSTRALE
CHAMAELEON
APUS
DORADO
Tarantula Nebula
MENSA
RETICULUM
ARA
OCTANS
South Celestial Pole
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